ELEMENTARY SCIENCE

BOOK I

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with an Introduction by

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BOOK I

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The illustrations have been drawn by Mrs C. G. Trew.

INTRODUCTION

It is essential that science should be taught to all pupils in schools. There are two reasons for this necessity. Science is part of culture; without some elementary knowledge of science we can have no conception of what we are, how we came into being, and what the world around us is. And secondly, our civilisation is founded so largely on science; agriculture, engineering and hygiene, all demand scientific knowledge, both to understand them and to practise them.

Science is the youngest subject in the school curriculum and until recently it has not received the attention which its importance demands. Moreover, in so many instances a part only of science has been taught, often physics or chemistry to boys, botany to girls. This book is the first of a series of three, which give a balanced elementary account of science, physical and biological. I believe that these books will be a real help both to teachers and pupils. For the former they outline a suitable course of teaching, obviating much difficult preparatory work in the other branches of science for the teacher who is principally a physicist, a chemist or a biologist. For the pupil the lessons in school will be impressed and made much more interesting by the simply worded accounts given in narrative style.

No really suitable book exists for the purposes outlined above, and, having had the pleasure of collaborating with Mr Webb and Miss Grigg in the preparation of their manuscript, I am convinced that their books will succeed.

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July 1934

PREFACE

SCIENCE AND THE SCHOOLS

The task of the science specialist in schools is, perhaps, the most difficult of all in the teaching profession. He is, often, a specialist himself in one or two branches of science. The Board of Education quite rightly, however, would like all children to be instructed in the general elementary principles of science as a whole.

If this desire of the Board of Education, and educationists as a body, is to be properly carried out an additional burden of preparation will have to be laid on the shoulders of the science teacher. Already he is responsible for the stock and requisition of material which is often more numerous in the number of items than the rest of the school stock put together.

Furthermore, the great value of science teaching lies in its practical application both in and out of school. In many instances the science teacher has neither a great deal of time for preparation nor a laboratory steward at his disposal. In these cases he finds that he has not sufficient time for the personal supervision that is necessary in the early stages. This lack of time is felt particularly when pupils are allowed to indulge in the delights of individual experimental work.

THE OBJECT

The object of this series of three books is twofold:

1. To stimulate the pupil to take an intelligent, and where possible an active, interest in all that goes on around him.

2. To lighten the burden of the science teacher as much as possible and so enable him to carry out his work in a still more efficient manner.

THE METHOD

Although the methods of teaching science are as numerous as the teachers, in the main the lessons can be divided into four sections. They are:

1. Descriptive and explanatory talk by the teacher together with demonstrations.

As the talk does not require definite personal effort on the part of the pupil it is, sometimes, not as successful as the teacher would like.

2. The writing of a summary of the lesson as notes. These notes represent the "essential minimum" of what the pupil should know in connection with the lesson.

3. Questions.

4. Individual experimental work where possible.

The authors propose to lighten the burden of the science teacher as much as possible by presenting:

(*a*) Interesting and stimulating reading matter.

This will require personal effort from the pupil, and partly replace the talk of the teacher. Consequently the teacher should be a little more free for preparation.

(*b*) Summary.

It will be satisfactory for the pupil to copy the summary directly from the text-book.

(*c*) Questions and exercises.

(*d*) Experiments with simple apparatus giving the stimulus to hobbies.

These experiments are in addition to those appearing under (*a*). *There is no necessity for the teacher to prepare Instruction Cards.*

The matter dealt with is concise, and the scientific phraseology is carefully treated in the earlier stages so that the pupil has every chance of grasping the subject. For example, the pupil commencing the study of science more fully comprehends the phrase "the force with which the air presses" than "the air pressure". Frequent use is made of synonyms and synonymous expressions.

It will be seen that the book is suitable for use in all types of schools in the town or country. The introduction of sections makes the work capable of being adapted to the varying conditions of the different schools.

A list of questions requiring short answers is included in the appendices. This is intended for use by the teachers in order that they may test, periodically, the efficiency of the work. The appendices also include advice regarding practical work, apparatus, etc.

Finally the particular attention of the teacher is drawn to Appendix B.

It will be understood that, whilst one of us (H. W.) has been responsible for the physical sciences, and the others (M. A. G. and H. M. F.) for the biological sciences, the work as a whole has received uniform treatment.

The reader will notice that there is not a summary to Section III. Such a large field has been covered in this section that it has been difficult to prepare a summary for the space allotted. If the pupil works carefully through the questions and experiments at the end of the section, it will be found that all the main, outstanding features of the first-year scheme of work in Biology will have been thoroughly dealt with.

H. W.

M. A. G.

SECTION I. AIR

Chapter 1

The reality of the air and its power

We often speak of vessels such as jugs, or even boxes, as being "empty" when actually they are full—full of a very important substance known as ***air***.

Air is one of the commonest and most plentiful substances that form our earth. It surrounds the earth to a depth of approximately two hundred miles, fills the deepest pit, and penetrates into every nook and cranny so that there is scarcely anything in the whole world that is "empty".

We are living at the bottom of a sea of air, and just as fish die when taken out of the sea we should die without air.

Although in the classroom we cannot see, smell, feel, hear or taste the air it is completely surrounding us and has in its possession enormous power. Even here it is pressing down on us and everything in the room with a force of 15 lb. on every square inch, i.e. almost a ton on every square foot.

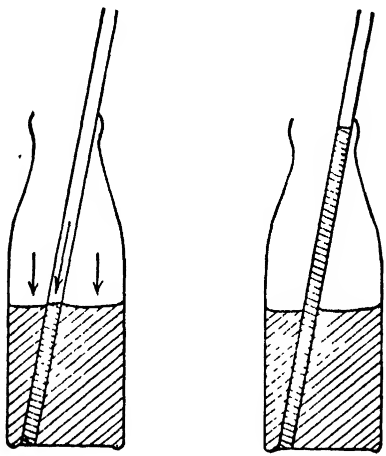
Winds

If you move your hand rapidly to and fro you will be able to feel the air. Sometimes the air itself moves and a wind is formed. Very rapidly moving air is called a gale. In this case the force of the air is so great that it can whirl us off our feet, tear roofs off houses, and uproot gigantic trees.

In a slight breeze the air moves at about				5	miles per hour.	
In a strong breeze	,,	,,	,,	20	,,	,,
In a gale	,,	,,	,,	40	,,	,,
In a storm	,,	,,	,,	60	,,	,,
In a hurricane	,,	,,	,,	75	or more miles per hour.	

Ways in which the air can help us

Air can be very helpful as well as destructive. Take, for example, when you had your bottle of milk this morning. When you first put your straw into your milk, the latter rose in the straw until it had reached practically the same height as that of the milk in the bottle (see Fig. 1 *a*). The arrowheads have been drawn in to show that the air is pressing on the milk in the



(a) (b)

Fig. 1.

bottle and on that in the straw. Now when you put your lips to the straw you withdraw the air from it, and the air pressing on the milk in the bottle literally pushes the milk up the straw into your mouth. This is the scientific explanation of what you call "sucking up".

How the elephant drinks

The elephant drinks in this way. His neck is so short that he is unable to bend his head to drink as other animals do. He, therefore, sticks his trunk in the water and withdraws air from

it so that it becomes full of water. When his trunk is full the elephant curls it up, places the open end in his mouth and squirts the water down his throat.

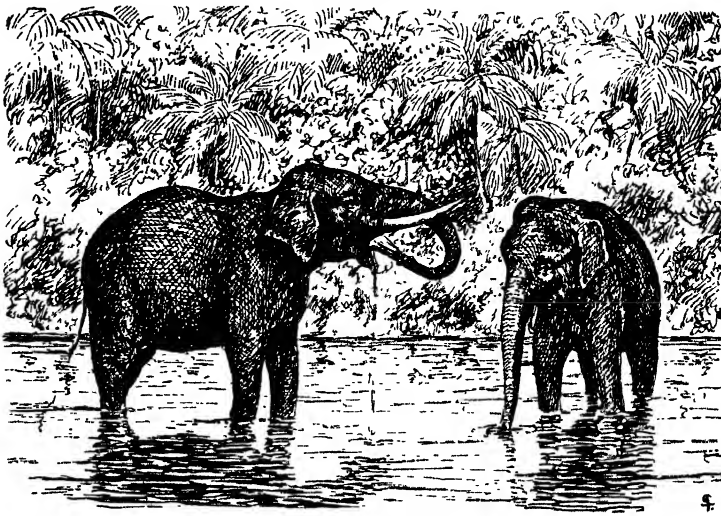


Fig. 2. It is pressure of the air that enables elephants to drink.

How to make a magic tin

Take a syrup tin with a press-in type of lid and knock a number of small holes in the bottom as shown in Fig. 3 *a*. Now fill it with water (you will have to think out a special way of doing this) and replace the lid.

You will find that you are able to hold the tin up in the air and none of the water will fall out through the small holes.

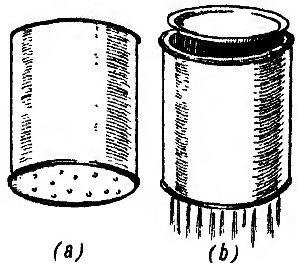


Fig. 3.

The water is kept in by the air pressing upwards against the holes with a greater force than that of the water pressing down.

Now remove the lid and the water will spray out through the

holes at the bottom. This is because the force of the air and water pressing downwards is greater than that of the air alone pressing upwards.

You have now seen that air presses not only downwards but upwards as well. The following experiments and accounts will teach you that air presses equally in all directions.

The water trick. Balancing water

Fill a tumbler with water and place a piece of paper over the mouth as shown. If you invert the tumbler carefully you will find that you can take your hand away from the paper and the water will remain in the tumbler. Hold the tumbler in any position and you will find that the water is still kept in. Again this is because the force of the air pressing against the paper is greater than that of the water.

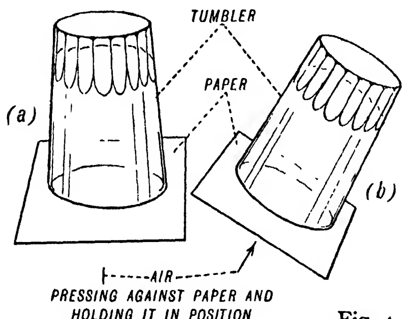


Fig. 4.

The "sucker"

The sucker is often moistened and pressed into position. This is only done to press out any air that there might be

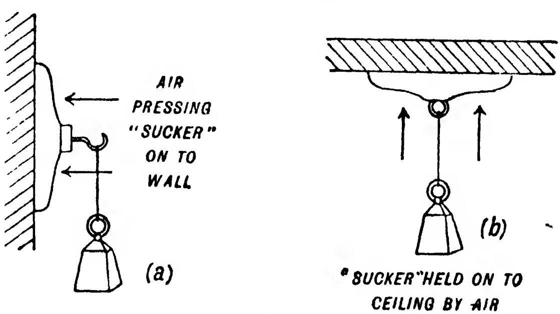


Fig. 5.

between the sucker and object to which it has to stick. The force of the air pressing on the outside of the sucker, as indicated by the arrows in Figs. 5 *a* and 5 *b*, holds it in position with sufficient power for it to support light weights.

The egg trick

Boil a new laid egg until it is quite hard, and then shell it. Next get a bottle with a neck a little too small for the egg to pass through. Warm the bottle carefully over a candle flame to drive out some of the air and place the egg in the neck of the bottle as shown in Fig. 6 *a*. After a while you will see the egg pass through the neck of the bottle.

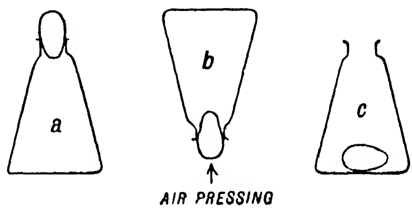


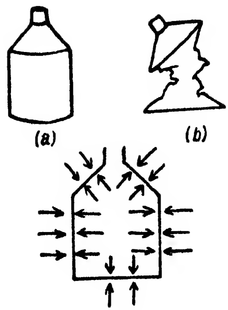
Fig. 6.

The explanation of this trick lies in the fact that some of the air had been driven out of the bottle by warming it over the candle flame. When the egg was placed in the neck as a kind of stopper the force of the air pressing on the egg from outside was greater than that from the inside. If, when the egg had partly passed through the neck of the bottle, you had inverted it as in Fig. 6 *b* the egg would still have been pressed into the bottle by the air pressing upwards.

To show the great force with which the air presses

Take a thin tin can such as is used by painters and boil a small quantity of water in it. After steam has been issuing from the neck for about a minute tightly cork it up and pour some cold water over the outside of the tin.

In a few seconds the tin will be crushed in as shown in Fig 7 *b*. The reason for this is that when the water boiled the steam drove all the air out of the can. After the can had been corked and cooled, the steam or water vapour inside was cooled and



(a) (b) (c)

Fig. 7.

condensed to a few drops of water so that there was very little pressure inside the vessel. So little pressure was there inside, that the force of the air, pressing on the outside, crushed the can in.

The reason that the tin is not crushed in, in the first place, by the pressure of the air outside, is because the air inside the tin presses outwards against it with a force as great as that of the air outside pressing inwards on the tin. This is indicated by the arrowheads in Fig. 7*c*.

A record balloon ascent

In 1862 two famous balloonists, Dr James Glaisher and Henry Tracy Coxwell, took off in a balloon from Wolverhampton with the object of ascending to a record height.

They achieved their object by rising approximately seven miles high. At this height, however, they suffered great hardship. Breathing was very difficult, and they began to bleed from the ears, eyes, nose and throat.

This bleeding puzzled the experts for a while until they realised that it was entirely due to the fact that the higher one goes in the atmosphere the rarer, thinner, or less dense it becomes.

The skins inside our noses, and the other organs from which Glaisher and Coxwell bled, are very thin and are known as ***membranes***. These membranes are so thin that the blood forced round our bodies by the pumping of the heart would burst through them were it not for the pressure of the air outside strengthening them.

As the two balloonists ascended, the pressure of the air became lessened so much that the membranes were unable to withstand the pressure of the blood. Consequently blood oozed through them.

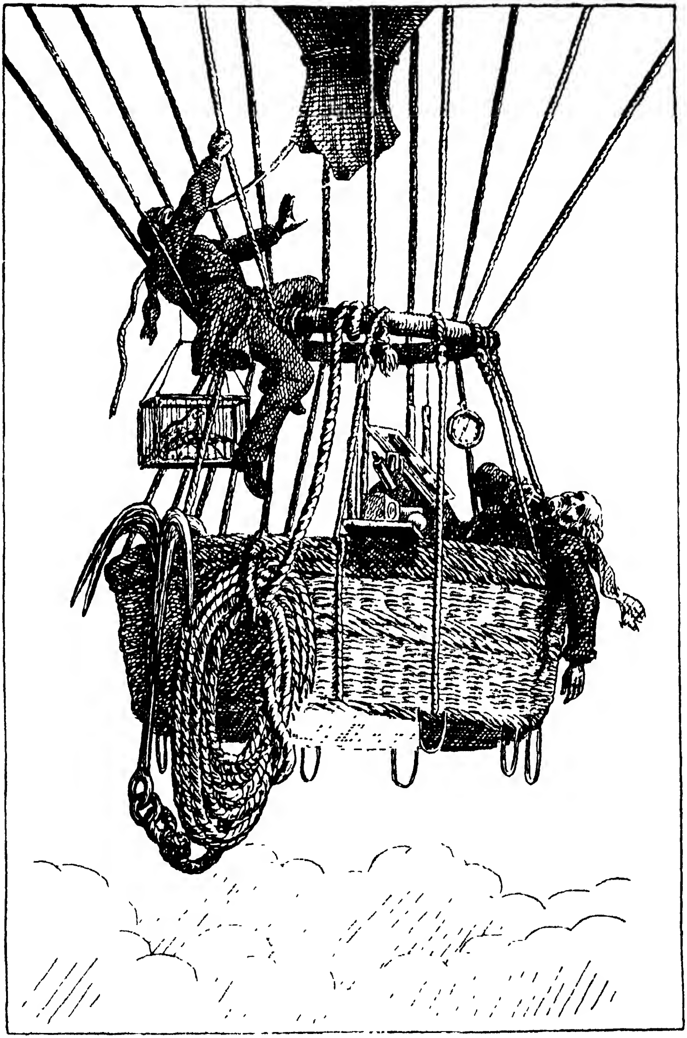


Fig. 8. Coxwell and Glaisher seven miles above sea-level. Dr Glaisher (on the right) is unconscious from loss of blood. Coxwell, whose hands were frostbitten, brought the balloon down safely by tugging at the valve rope with his teeth. The valve rope when pulled, opens a valve in the top of the balloon and allows gas to escape.

How the bicycle pump works

Tyres of bicycles and motor-cars are filled with air which is at a greater pressure than that of the air outside. This ***compressed*** air, as we call it, makes the tyres swell out and enables them to take up some of the shocks or bumps of the road. The pressure of the air inside the tyres of small cars is approximately 25 lb. on every square inch. In the case of lorries the pressure inside the tyres is sometimes as much as 80 lb. per square inch, whereas, you will remember, the pressure of the air we breathe in is about 15 lb. per square inch.

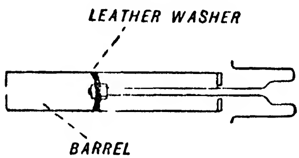


Fig. 9. A section of a bicycle pump

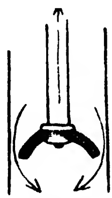


Fig. 10

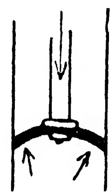


Fig. 11

The pump used for blowing up tyres consists of a straight barrel inside which a plunger moves up and down. Fitted to the bottom of the plunger is a leather disc softened by grease. This disc will only allow air to flow past it when the plunger is being drawn outwards (see Fig. 10). When the plunger is pressed inwards the disc, valve, or washer is pressed tightly against the walls of the barrel by air trying to escape (see Fig. 11). This air is compressed and forced out of the pump past the tyre valve into the tube.

The tyre valve

(A valve is a covering or door to an aperture or hole which will open in one direction only.)

The tyre valve is a device which prevents the air from escaping once it has been pressed into the inner tube of the tyre. It consists of a small metal tube closed at one end but with a hole in its side. This closed end is enclosed in a piece of thin rubber tubing (see Fig. 12).

Air forced from the barrel of the pump blows past this rubber tubing (see Fig. 13) and enters the tyre. When the pumping ceases the pressure of the air inside the tyre forces the rubber against the hole of the valve and so closes it.

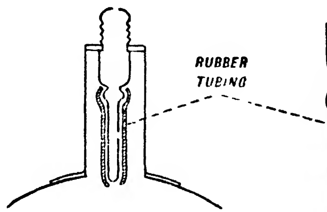


Fig. 12. A bicycle tyre valve.

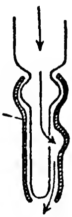


Fig. 13. A bicycle tyre valve with air passing through it.

The lift pump

This type of pump, assisted by the pressure of the atmosphere, is able to raise water from a well.

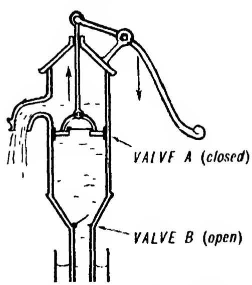


Fig. 14. Water pump with bucket ascending.

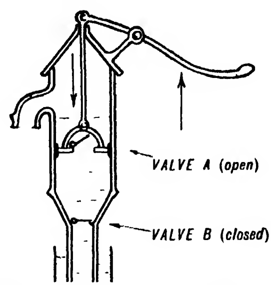


Fig. 15. Water pump with bucket descending.

When the valve *A* is raised by depressing the handle, the pressure of the air forces water from the well up into the barrel of the pump past valve *B* (see Fig. 14).

When valve *A* descends its pressure closes the bottom valve and opens itself so that the water in the barrel passes above it.

When the first operation is again repeated the water above the top valve is lifted and passes out through the spout of the pump.

A great discovery

Lift pumps were known and used during the seventeenth century. A Duke of Tuscany (Tuscany is a province in Italy) had one to obtain water from a well situated in the grounds surrounding his house. One summer he was unable to obtain water from the well by means of the pump. The Duke sent for Galileo, a very clever seventeenth-century Italian scientist, to investigate the cause of the trouble.

Fig. 16. Galileo (without hat) at the Duke of Tuscany's well.

The pump was examined and found to be in good condition. Then Galileo found that it would raise the water about 25 feet, but as the water in the well had fallen between 35 and 40 feet below the level of the ground owing to a very dry summer it could not be delivered from the spout of the pump.

Later Galileo and one of his pupils named Torricelli discovered that under very good conditions the pressure of the air will support a column of water not more than 34 feet high at sea-level.

The barometer

Torricelli proved his discovery to be true by using mercury, a silvery looking metallic liquid which is $13\frac{1}{2}$ times heavier than water.

He took a glass tube about 3 feet long open at one end and closed at the other. He filled this tube with mercury and then, placing his thumb over the open end, inverted it into a trough of mercury. When the open end was below the level of the mercury in the trough Torricelli removed his thumb and the liquid in the tube fell until it was about 30 inches above that in the trough. There it remained supported by the pressure of the air.

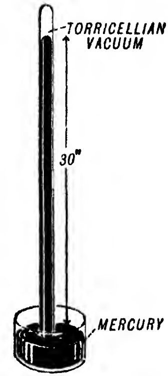


Fig. 17.

Torricelli called his apparatus a ***barometer***, because this word means ***pressure measurer***.

Nowadays we have several kinds of barometers.

A column of mercury 30 inches high and one square inch across weighs 15 lb., and as a column of mercury of this height can be supported by the pressure of the atmosphere, the pressure of the latter must be 15 lb. on every square inch.

In a mercury barometer the space above the liquid in the tube is absolutely empty.

A perfectly empty space is called a ***vacuum***, and that at the top of the mercury column in a barometer is often referred to as the ***Torricellian vacuum***.

How the barometer is used to foretell the weather

During fine dry weather the pressure of the air is greater than when the weather is damp or rainy. This variation of air pressure will cause a corresponding variation in the height of the mercury column it supports. Thus if the barometer's mercury column is 30 inches, or more, we may definitely expect fine weather.

On the other hand, if the mercury column is less than 29 inches high, wet, and possibly stormy, weather may be expected.

There are several different kinds of mercury barometers on the market, some of which have indicators showing what type of weather is to be expected.

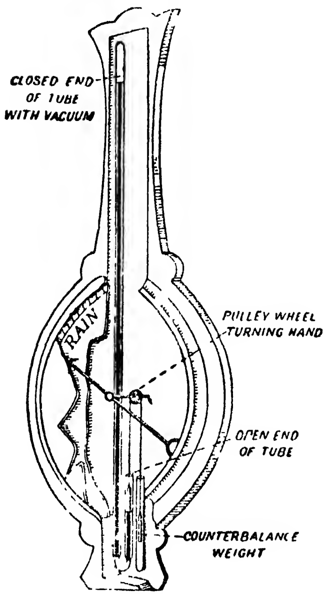


Fig. 18. A self-weather-recording barometer.

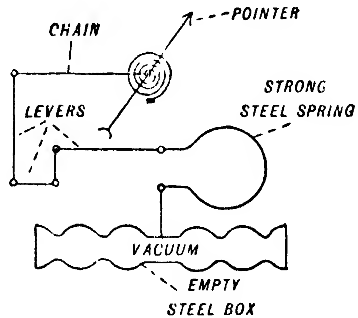


Fig. 19. A section to show how the aneroid barometer works.

The aneroid barometer

The aneroid barometer is one that works without using any liquid at all—***aneroid*** meaning ***without liquid***.

It depends for its action upon a small steel box from which all the air has been withdrawn before closing it up. The strength of the steel prevents the box from being crushed in as was the tin in the experiment mentioned on pages 5 and 6, but the lid will either bulge out slightly or be pushed in slightly as the pressure

of the air is less or more. The centre of the lid is connected by a set of levers which actuates an indicator that shows the air pressure on the dial of the barometer.

The air becomes less dense the higher we go up into it. This is indicated by the barometer ***falling***—an expression used when the barometer shows a decrease in the pressure of the air.

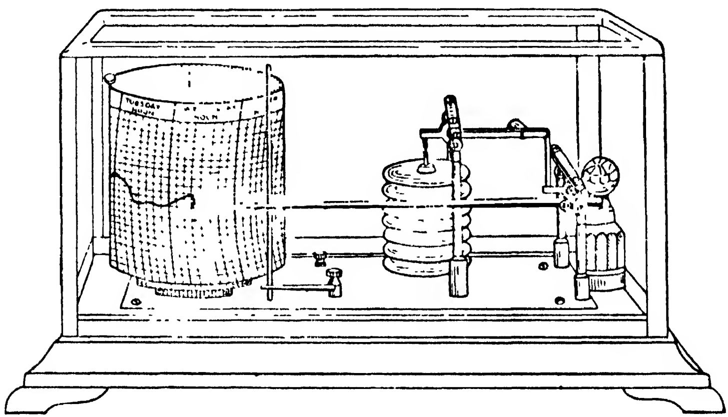


Fig. 20. A barograph.

The barometer falls approximately 1 inch for every rise of 1000 feet. Aneroid barometers marked off in thousands of feet are used in aircraft to show the height at which the machines are flying.

Swallows nearly always fly low before rain. This is because the air is less dense and unable to support the insects on which these birds feed.

The barograph is a self-recording aneroid type of barometer. A picture of one is shown above.

The barrel on the left is a kind of clock which is made to rotate slowly by a clock spring and set of wheels similar to those found in everyday timepieces. The indicating needle marks the chart on the barrel as it slowly rotates.

Birds and aeroplanes

Both birds and aeroplanes are heavier than air, yet in spite of this they can rise and remain aloft for considerable periods. This is largely due to their forward movement (or the movement of air against them) and the streamlined effect of their

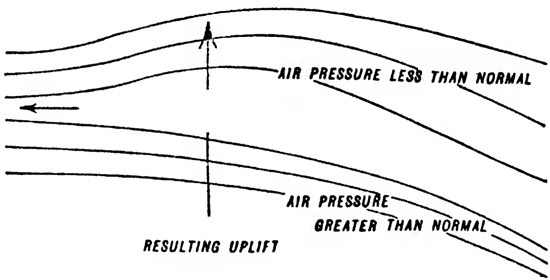


Fig. 21. Section of aeroplane wing.

bodies—in particular their wings or planes. This effect, together with the movement, causes the air pressure below the wing to become greater whilst that above becomes less. The result is an uplift (Fig. 21).

Chapter 2

Air and its gases

In olden times people used to think that the world and all it contained were made up of four substances—earth, air, fire and water. These four things were regarded as simple substances or ***elements***, meaning materials consisting of one substance only.

Since those times air has been shown to be a mixture of several kinds of gases similar to steam. Like steam all these gases are invisible because they do not possess colour. There are, however, a few gases which can be seen because they are coloured whilst some others can be detected by their smell.

Burning

Very often, when your fire will not burn at home, you take a poker and lift up some of the coal. By lifting the coal you make room for air to get into the centre of the fire. Sometimes blow-bellows are taken and air is blown into the fire-place. The result is that the fire burns much more brightly, owing to the fact that it has a plentiful supply of air.

The blacksmith usually has a fire of glowing embers in his smithy all day long. When he wishes to make iron red or white hot, in order to shape it, he blows his fire with air from his bellows, and the glowing embers soon become almost as hot as a blazing furnace.

From this you will see that air is very important for fire. The part that air plays in maintaining fire, however, was unknown until about one hundred and fifty years ago, when an experiment was performed similar to that described below. This experiment you will be able to do for yourselves.

To show what happens to the air when something burns in it

If a bell jar is placed over a lighted candle which is standing in a dish of water, the candle will continue to burn for a short while and then the flame will gradually die out. At the same time the water will rise inside the jar.

This experiment shows that some of the air was used up by the candle when it was burning.

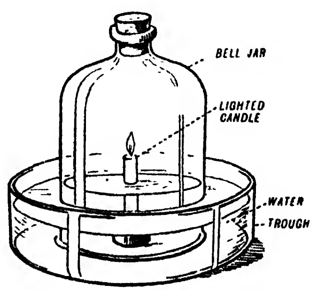


Fig. 22.

If the stopper of the bell jar is now removed and a lighted taper is lowered into the air that was not used up by the candle the light will be extinguished or "put out". This experiment should be repeated to show that the extinguishing of the candle

is not an accident. When the lighted taper is lowered into a bell jar of unused air, you will find that it will continue to burn.

Therefore, when substances like candles burn in air they use up a part of it, and that air which remains will not allow of any further burning.

That part of the air used up by the candle whilst it is burning is called ***oxygen***.

Burning phosphorus

Phosphorus is a substance (something like orange-coloured cheese) that catches fire so readily that it is dangerous to handle and has to be kept in water in case it should catch fire by itself. Owing to the dangerous nature of phosphorus the following experiment is best done by your teacher.

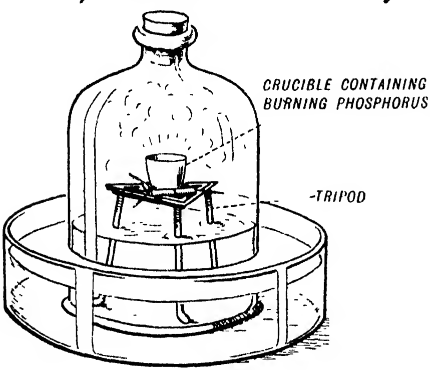


Fig. 23.

Another more satisfactory method of using up the oxygen inside the bell jar of the previous experiment is to place the jar over a piece of phosphorus burning in a small dish or crucible, which is supported as shown in Fig. 23. A piece of phosphorus about four times the size of a pin-head will be sufficient.

Gradually the phosphorus uses up all the oxygen in the jar as it burns, and then goes out. Meanwhile the water rises in the jar to take the place of the oxygen that was in the air.

Whilst the phosphorus was burning dense white clouds, called ***fumes***, were given off. They were caused by the oxygen joining with the phosphorus. These dense white fumes are very poisonous, but you will notice that they seem to disappear in a few moments. This is because, like sugar, they dissolve easily in the water.

After the experiment has stood for about ten minutes you will find that the water has risen and occupied about one-fifth of the space originally taken up by the air.

Therefore about one-fifth of the air is oxygen.

The heads of matches always contain some phosphorus, and if you strike a match and watch carefully you will notice the white fumes given off. Tell your father to wait until the wood begins to burn before he lights his pipe, because although there are not enough white fumes to poison him they are sufficient to spoil his smoke; and, if he is in the habit of using a lot of matches, there is sufficient poison to make him ill.

Chemical changes

If the inside of a jar is moistened and about a teaspoonful of ***clean*** iron filings dropped in they will stick to the sides of the

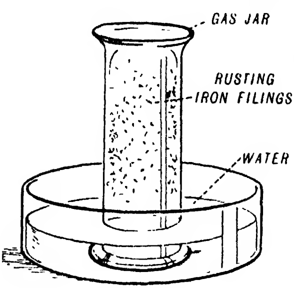


Fig. 24.

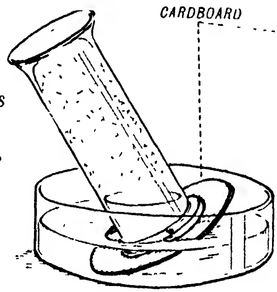


Fig. 25.

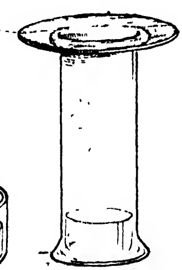


Fig. 26.

jar when shaken about. Fig. 24 illustrates a jar that has been treated in this manner and left inverted in a bowl of water. In a few hours the filings will show signs of rusting. After several days the rusting will cease and the water will have risen up the jar and have taken up about one-fifth of the room formerly occupied by the air. Try this experiment for yourselves, and when the rusting has ceased raise the jar slightly in the water and slip a piece of cardboard over the mouth. Then lift the jar out of the water, invert it, and place it on the bench.

Take care to keep the cover on the jar to prevent any fresh

air from getting in. If a lighted taper is then put into the jar the flame will be extinguished immediately.

Therefore the iron, in rusting, has used up the oxygen of the air.

When any substance alters its nature by joining with another substance to form a new material a chemical change is said to have taken place.

The iron joins with the oxygen of the air to form a new substance that we call "rust". The chemical name of this new substance is ***iron oxide.***

The white fumes that are produced when phosphorus burns consist of fine particles of oxide of phosphorus. When the candle burns, the grease, which is mostly carbon, joins with the oxygen of the air to form a gas which is known as carbon dioxide.

There is, then, very little difference between "rusting" and "burning", for in each case the substance in question joins with the oxygen of the air to form an ***oxide.*** The only differences lie in the fact that the phosphorus becomes an oxide much more quickly than does the iron. From this you will see that ***burning is "quick rusting".***

The air left behind in the jars of the previously mentioned experiments when the candle, phosphorus and iron have finished burning or rusting is practically all ***nitrogen.***

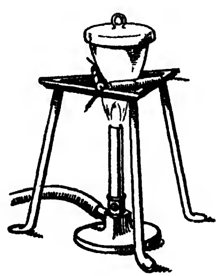


Fig. 27.

It is natural to expect that substances should weigh heavier when they have burnt or rusted as a result of having joined with another substance—oxygen. Yet looking at a candle burning away this is difficult to believe. The wax of the candle, however, does not burn away to nothing—the new substances that are formed are mostly gases which float away and mingle with the air. If we were able to collect all these new substances and weigh them, we should find that they were heavier than the original candle.

This can be proved by "rusting" a metal called magnesium. If a weighed piece of magnesium ribbon is heated over a Bunsen burner in a weighed crucible, the lid of which should be raised slightly, occasionally, to allow air to get to the metal, it will be found that the white material left behind as a result of the "quick rusting" is slightly heavier than the original metal.

The white material is magnesium oxide.

Lead, a bright silvery looking metal, becomes dull when left in the air. This is because oxygen from the air together with the lead form a thin layer of "rust" or lead oxide on the surface of the metal. The tarnish of silver, or copper, or brass is formed in this way, and is actually oxide of silver, or of copper, or of brass.

The prevention of rust

The many uses to which iron is put make it necessary that this metal should not be allowed to rust or ***oxidise***, and so become rotten.

The so-called "tins" which are used to hold milk, tinned fruits and other foodstuffs are not pure tin at all. They are made from thin sheets of iron that have been cleaned and dipped into a bath of molten tin. The tin prevents the air from rusting or ***oxidising*** the iron, and oxidises itself so slowly that it can be used without danger.

Galvanised iron is made by dipping cleaned sheets of iron into baths of molten zinc. Zinc, like tin, is a metal which oxidises very, very slowly.

Ironwork is frequently painted to prevent the air and moisture from rusting and rotting it. Permanently attached to the underside of the Clifton Suspension Bridge at Bristol is a small platform which runs along the whole length of the bridge. This platform is used by painters who are at work on the bridge almost continuously throughout the year.

About fifty men are regularly employed throughout the year doing nothing but paint the steelwork of the great Forth Bridge

in Scotland. During this time many tons of paint are used to keep the metal free from rust.

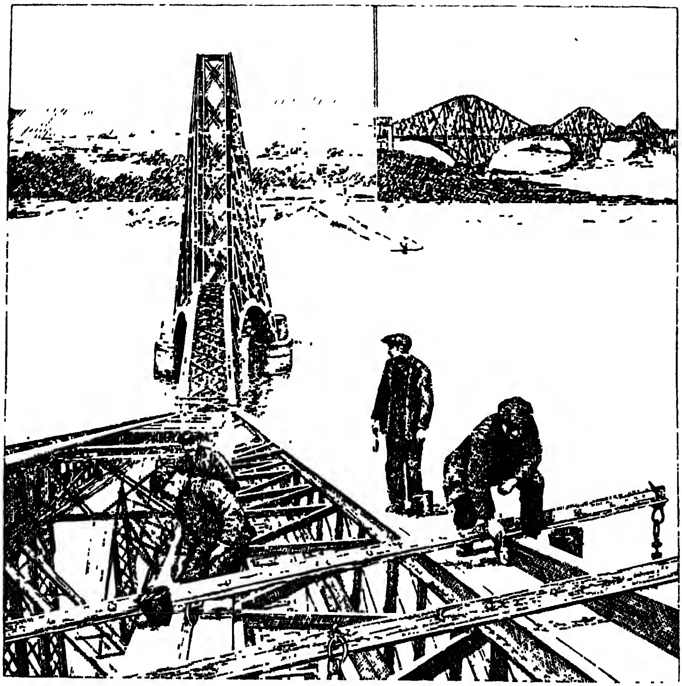


Fig. 28. Painters at work on the Forth Bridge.

How oxygen can be made

There are many substances which are very rich in oxygen, and some of them, in particular one called potassium chlorate will give up their oxygen when heated.

If some of this potassium chlorate is heated in a hard glass tube, oxygen gas will come off and can be collected by displacing water in the apparatus shown in the figure below. This is done by inverting a gas jar full of water over the end of the delivery

tube. The oxygen comes along this tube and bubbles up into the gas jar, from which it pushes the water.

Manganese dioxide added to the potassium chlorate causes the latter to give up its oxygen more readily. About half as much manganese dioxide as potassium chlorate should be used, the mixture of the two being known as "oxygen mixture".

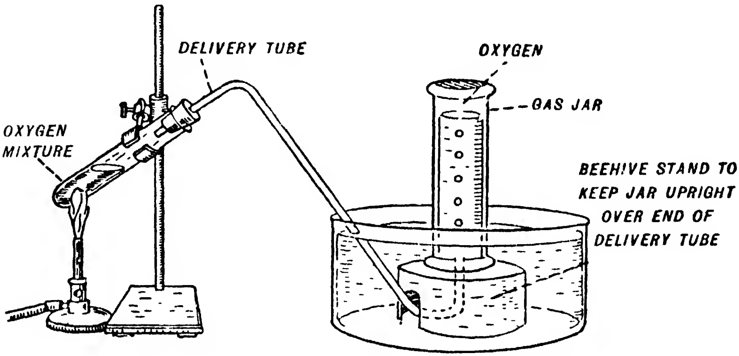


Fig. 29. The laboratory method of preparing oxygen.

The properties or special features of oxygen

If different burning substances are lowered into the oxygen by means of a deflagrating spoon they will burn much more brightly and rapidly. A glowing splint or ember will burst into flame if lowered into oxygen.

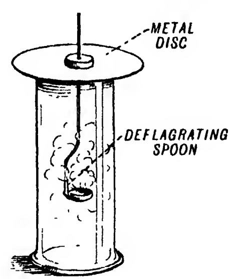


Fig. 30.

The resulting oxides of non-metals, like phosphorus, sulphur or charcoal, will all, to a greater or lesser extent, dissolve in water to form substances we call acids.

Oxygen renders great assistance in helping to kill germs. Many people who have sore throats suck tablets made of potassium chlorate, which is stated to give up oxygen to the tissues of the body. Potassium permanganate is another substance very

rich in oxygen, and is largely used as a gargle. A few crystals of the substance dissolved in a tumblerful of water make an excellent gargle. Both the potassium chlorate and the permanganate can be purchased from any chemist.

Nitrogen

Nitrogen, a gas that forms about four-fifths of the air, is often referred to as "inactive gas". This is because it will neither burn nor allow things to burn in it. Nitrogen very seldom, an then not readily, joins with other materials to form new sub stances or ***compounds***, as does its companion gas of the air —oxygen.

N.B. A compound is a substance made up from two or more materials that have been joined together chemically. Lead oxide, for example, is a compound of lead and oxygen.

Apart from the fact that it may be a little warmer, the nitrogen that enters our lungs when we take in air is breathed out again unchanged. In spite of this, however, our bodies, like those of other animals, and plants require nitrogen.

The roots of plants take in nitrogen, in the form of nitrates or nitrites in solution, from the soil. In the plant these are formed into more complicated substances called proteins. These proteins contain carbon, hydrogen and oxygen as well as nitrogen.

By eating plants, or animals which have fed on plants, such as cows and sheep, these proteins containing nitrogen get into our bodies.

During a thunderstorm the oxygen and nitrogen in the immediate vicinity or neighbourhood of a flash of lightning join together and form a compound. This compound is washed down by the rain into the soil, where it joins with other substances to form nitrates. In this way the lightning does us some good by helping to make the ground more fertile.

Nitrate fertilisers are now made in factories by blowing air through a huge electric spark, which is similar to a small flash

of lightning. This is done mostly in Norway, where, owing to the numerous waterfalls, electricity is cheap.

Carbon dioxide

Although the air is made up almost wholly of oxygen and nitrogen there are present very small quantities of other gases. Chief amongst these is carbon dioxide. This gas, like oxygen and nitrogen, is colourless, tasteless, and does not smell. Its presence can be detected, however, by the fact that lime water will go milky when this gas bubbles through it.

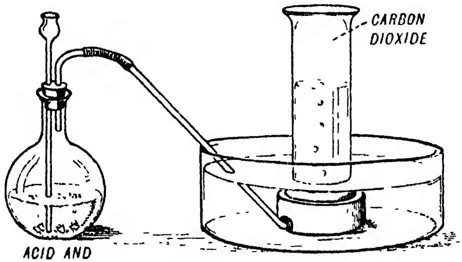


Fig. 31.

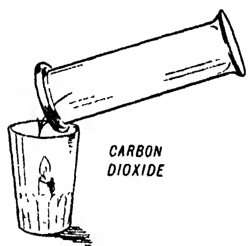


Fig. 32.

Lime water left exposed to the air, in a saucer or other open vessel, for a week will be found to have gone slightly milky. This shows the presence of a small amount of carbon dioxide in the air.

Carbon dioxide can be made by pouring acids on to substances called carbonates. Marble and limestone are two forms of a carbonate called calcium carbonate.

Although the gas will dissolve fairly readily in water, quite a fair amount can be collected as was the oxygen on page 21. Carbon dioxide is half as heavy again as air, and can be poured from a jug like water. It will also extinguish at once a light.

If a short piece of lighted candle is put into a tumbler, a gas jar full of carbon dioxide can be poured into it as shown in Fig. 32, and the light will "go out" or be extinguished immediately. This is because it surrounds the flame and prevents any further oxygen from getting to it.

Fire extinguishers

The fact that carbon dioxide will extinguish flames is turned to great advantage in the construction of fire extinguishers.

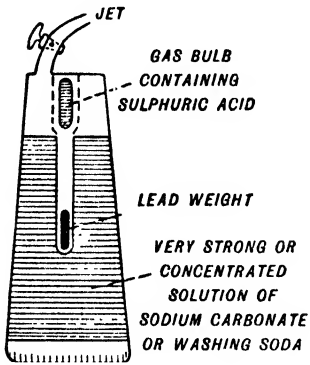


Fig. 33. A section of a chemical fire extinguisher.

One form of fire extinguisher is shown in Fig. 33. The container is generally made of metal lined with pitch, and contains a very concentrated solution of carbonate of soda, or washing soda.

When the extinguisher is required for use it is quickly tilted so that the lead weight causes the glass bulb to break. The acid mixes with the carbonate which gives off large volumes or quantities of carbon dioxide. When the tap is turned on a spray of liquid and carbon dioxide issues from the jet or nozzle. The carbon dioxide chokes the flames and the water takes away the heat from them. In some similar forms of this apparatus only carbon dioxide comes out through the nozzle.

Baking powder, mostly bicarbonate of soda, when it is heated will give off carbon dioxide. It can, therefore, be used as a fire extinguisher, for when it is thrown on the fire it gives off carbon dioxide which chokes the flames.

There are other means of shutting air out from a

Fig. 34.

fire or flames and so extinguishing them. Wet sand is good for this purpose. Persons who are on fire should be placed on the floor and rolled in heavy rugs or blankets.

Mineral water drinks

When you pour out a glass of lemonade you will notice that it is bright and sparkling and that it gives off bubbles of gas.

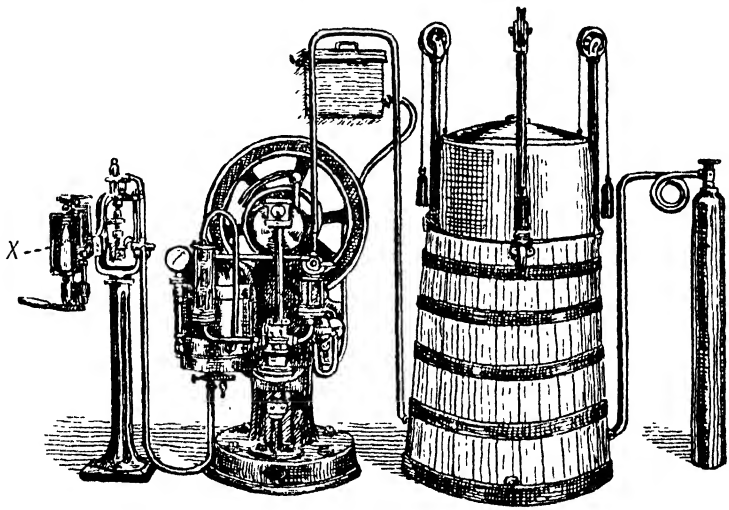


Fig. 35. A bottling machine. Carbon dioxide from the cylinder on the extreme right is forced into the bottle of liquid which is placed at *X*.

The bubbles are bubbles of carbon dioxide, which is forced or pressed into the liquid by a bottling machine.

Soda water is also made in this way.

The carbon dioxide used by the bottling machine is kept in large steel cylinders. The gas is forced into these cylinders at such a great pressure that it becomes so tightly packed that it becomes a liquid.

Breathing

From the time we are born until the day of our death we are continually taking air into our lungs and emptying them of it

again every few seconds. Some of the oxygen of the air that we breathe in joins with the body and, in doing so, creates a certain amount of bodily heat.

The oxygen that is used up by the body is replaced by carbon dioxide which the body gives up to the lungs. Consequently the air that we breathe out contains less oxygen than we breathed in, and, in addition, some carbon dioxide. This can be proved by breathing out through a tube into a glass of lime water. Immediately the lime water will go milky.

A low trick

The quack doctor who visited country fairs years ago used this knowledge to sell his worthless medicines. He would get a sickly member of the audience to breathe down a tube into what he pretended was water, but which was actually lime water When the lime water turned milky the so-called doctor would tell the crowd that the milkiness was due to a dirty interior. The alarmed patient was then persuaded to take a dose of "quack", and then made to breathe into another glass of water—real water this time. Of course the water remained clear, the crowd marvelled, and the "doctor" sold plenty of "quack".

Burning, breathing, rusting

In each of these three processes oxygen is used, oxides are formed, and heat is given off.

The only differences lie in the fact that in burning, or combustion as it is sometimes called, the oxygen joins so quickly with the fuel, i.e. the substance which burns, that sufficient heat is produced for a fire.

In breathing, when oxygen joins with a substance in the body to form carbon dioxide, heat is produced which helps to keep the body warm. It is for this reason that people breathe more deeply in winter than in summer.

When iron joins with oxygen to form rust it does so very slowly, and although heat is formed its formation is so slow that it leaks away again before it has a chance to warm the iron.

It is interesting to notice here that oxygen is slightly soluble in water, and owing to this fact fishes are able to get their supply of oxygen. They take oxygen from the water by means of their gills.

Fish cannot live in boiled water.

Two very serious problems

Perhaps these problems have already occurred to you in reading through this chapter. They are:

1. With all the burning, breathing and rusting that goes on every minute of every day—will the air's supply of oxygen all be used up eventually? and,

2. Is the carbon dioxide, that heavy gas, which is being sent out of the mouth of every animal several times each minute, likely to become such a large fraction of the air that we shall either be choked to death, or forced to live in mountains, or tall trees, or balloons so high that the heavy gas cannot reach us?

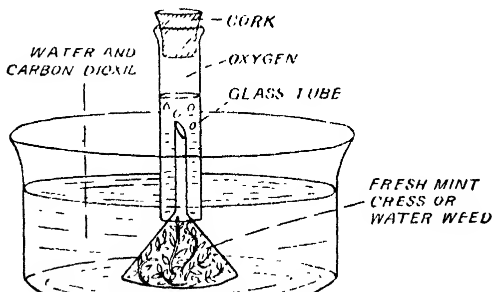


Fig. 36.

Happily for all things living, the answer to both of these questions is "No!"

The reason for this is that all green plants take in or breathe in carbon dioxide when exposed to light. In exchange for this carbon dioxide the plants give back to the air pure oxygen. This behaviour of plants is entirely dependent upon the combined action of their green colouring matter and light. Consequently the air will have a supply of oxygen as long as there are green

If apparatus is fixed up similar to that shown in Fig. 36 and placed in the sunlight the green leaves will be seen to give off bubbles of gas. These will rise and collect in the tube. The experiment will work extremely well if a large volume of water and plenty of water-weed are used. When sufficient gas has collected in the tube remove the cork and insert a glowing splint. The splint should be relighted, proving the gas to be oxygen.

The water may be charged with carbon dioxide by bre
into it with the aid of a glass tube.

The aquarium

Since fish breathe in oxygen which is dissolved in the water, and breathe out carbon dioxide, it is a good plan to arrange for plants to grow in the aquarium. When the light falls on them the plants will take up the carbon dioxide that the fishes breathe out, and give back oxygen to the water.

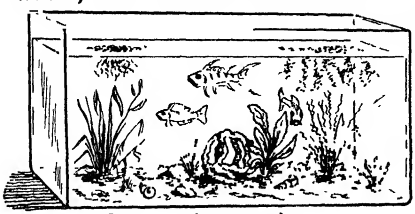


Fig. 37. An aquarium.

The air cycle

Animals by breathing and blood circulation join the carbon in their tissues with the oxygen of the air to form ***carbon dioxide.*** This they breathe out.

Green plants in sunlight take in carbon dioxide and divide it into ***carbon*** and ***oxygen.*** The carbon they retain as food for their tissues, and they give back to the air ***oxygen.***

Other gases in the air

In addition to nitrogen, oxygen and carbon dioxide, there are, also, very small or minute quantities of other gases in the air. Chief amongst these is water vapour. The amount of water vapour present in the air depends, of course, on the climatic conditions. The other gases present are ***argon***, ***neon***, ***krypton***, ***xenon*** and ***helium***. All of them, like nitrogen, are very inactive. Helium, which is a very light gas, is largely used for filling the gas bags of balloons and airships.

The composition of the air by volume

Nitrogen	78·03	per cent.
Oxygen	20·99	,,
Carbon dioxide	0·03	,,
Water vapour and other gases ...	0·95	,,

Solids, liquids and gases

Up to the present we have been considering substances that we have called ***gases***. Many substances which exist as gases, however, may also be found in two other forms—***liquids*** or ***solids***. Best known amongst these substances is water. In very cold weather the water in the streets is found as a solid known as ***ice***. In very warm weather it disappears from the streets, because, as you know, it has changed into a gas, water vapour, and has mixed with the air.

Molecules

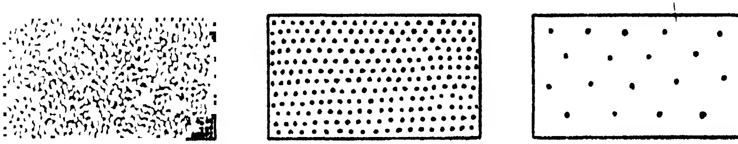
Quite a number of substances when they are heated change from a solid to a liquid, and, as they are still further heated, change from a liquid to a gas. Whilst all these changes are taking place the substances are generally growing larger and larger.

On the other hand, when these gases are cooled they change first to a liquid and then to a solid, and, in doing so, get smaller and smaller.

Water is something of a freak substance, because as it is

cooled it gets smaller and smaller and smaller, and then just before it changes into ice it becomes a little larger.

In order to understand why substances behave in this manner it is necessary to know how they are made up. Scientists tell us that all substances must be made up of very small particles, so small that there are millions of them in one drop of water. These very small particles they call ***molecules***. Now in solids these molecules are packed tightly together and seem to hold on to each other, so that we find it hard to part them. When



(a) (b) (c)

Fig. 38. (*a*) SOLID. Molecules tightly packed and holding on to each other so that all together they form a solid lump. (*b*) LIQUID. Greater distance and less attraction between the molecules. (*c*) GAS. Enormous distance and no attraction between the molecules.

they are heated, however, they push each other further apart, and as the heating continues the whole substance eventually turns into a liquid, which can be parted easily. More heating pushes the molecules so far apart that they disappear from view by turning into a gas.

The diagram above gives you some idea of the distances between the molecules of a substance in its three states, viz. solid, liquid and gas.

Most gases can be liquefied by compressing them, or squeezing them together, whilst they are being cooled. Liquid carbon dioxide is made in this way. Many of the subsequent liquids can be solidified by the same process.

Summary

Air surrounds the earth to a depth of about 200 miles. It fills every nook and cranny, so that there is hardly anything that is "empty".

A perfectly empty space is called a ***vacuum***.

Winds are moving air.

The force with which the air presses is very helpful to us in many ways. It assists us to drink through straws and the elephant through his trunk. It holds "suckers" on to objects in any position—all with the force of about 15 lb. on every square inch. Inside our noses (as in other parts of our bodies) the skin is very thin and delicate. It is called a ***membrane***. By its pressure the air helps this skin to stop the blood inside the body from bursting through.

The pressure of the air will hold up a column of water about 34 feet in height, or a column of mercury 30 inches in height. Such a column of liquid is known as a ***barometer*** or ***pressure measurer***. It is of great help in foretelling the weather. In fine weather the pressure of the air is greater than in bad weather and so the "barometer goes up". Some barometers do not contain liquid at all. They are known as ***aneroid barometers*** and are often used in aeroplanes to show how high the machine is flying. For every 1000 feet up the barometer shows a fall of 1 inch of mercury.

Birds and aeroplanes can keep up in the air ***only*** by moving against the air. As they move forwards the air presses against the underside of their bodies or wings.

The burning of substances, the breathing of animals, and the rusting of metals are very similar performances. In all three cases oxygen is used up and new substances called ***oxides*** are formed, whilst heat is given off. Burning is the quickest action and rusting is the slowest. The heat given off in breathing helps to keep animals warm. Because of this animals breathe more

deeply in winter than in summer. In the case of rusting the heat is formed so slowly that it leaks away before it is sufficient to be noticed.

As a result of what we breathe out there is always present in the air a small quantity of ***carbon dioxide***. This gas can be detected easily because it turns lime water milky.

Carbon dioxide is a heavy gas and extinguishes flames.

Fire extinguishers contain two liquids—strong washing soda solution and sulphuric acid—which, when mixed together, give off large volumes of carbon dioxide.

The little bubbles that you see in mineral waters, such as fizzy lemonade, are bubbles of carbon dioxide. Carbon dioxide makes the drink sharp, sparkling and pleasant.

Green plants under the influence of daylight take in carbon dioxide and give out oxygen.

All substances are made up of very, very small particles called ***molecules***.

When substances are heated they swell or expand because the heat forces the molecules further apart. Continued heating will push the molecules so far apart that solids change to liquids and liquids to gases. An exception to this expansion is ice when it changes to water.

Questions

1. Describe one of the ways in which the air is helpful to us in our daily lives.

2. The force with which the air presses is much more enormous than is commonly supposed. Say how you would prove this to your friends.

3. With the aid of diagrams describe how the bicycle pump and the tyre valve work.

4. What is a lift pump? How does it work? Illustrate your answer with diagrams.

5. What is a mercury barometer? For what purposes is it used?

6. Describe the aneroid barometer. How can airmen tell how high they are flying?

7. Birds and aeroplanes are heavier than the air. How do they manage to fly about in it?

8. Show how burning, breathing and rusting are very similar actions.

9. (*a*) What are oxides? Mention how two of them are formed.

(*b*) What is "rust"? Describe how two of these "rusts" are formed.

10. How do we prevent the formation of rust?

11. Say what you know about oxygen, nitrogen, and carbon dioxide.

12. Why is carbon dioxide used in extinguishing flames? Describe some form of fire extinguisher.

13. Why is some lemonade "fizzy"?

14. How is it that the oxygen that we breathe in is replaced in part by carbon dioxide when we breathe out?

15. With all the burning, breathing and rusting that is going on is it possible that the air's supply of oxygen will give out? Why?

16. How do fish breathe? Why is it a good thing to grow green plants in an aquarium?

17. What is a molecule? What are the differences between ice, water and steam? What are the two ways of changing gases to liquids and liquids to solids?

Practical Work

A. TITLES OF EXPERIMENTS

The numbers given are those of the pages which will give you the necessary instructions.

The experiments printed in italics are intended for demonstration by the teacher. This is in order either to save time or because the experiments are dangerous.

1. To make a magic tin and to show how it works. 3, 4.
2. The water trick. 4.
3. *The egg trick.* 5.
4. To show the great force with which the air presses. 5, 6.
5. *To show what happens when phosphorus burns in air.* 16.
6. To show what happens when a candle burns in air. 15.
7. To show what happens when iron rusts in air. 17–18.
8. *To show what happens when magnesium rusts.* 19. *In this experiment it will be necessary to make the following weighings:*
   (*a*) *Weight of crucible.*
   (*b*) *Weight of crucible + magnesium (before heating).*
   (*c*) *Weight of crucible + magnesium (after heating).*
9. *To make oxygen.* 20, 21.
10. *The properties of oxygen.* 21, 22.
11. To make carbon dioxide and to study its properties. 23.
12. To show that green plants give off oxygen in daylight. 27, 28.

B. ADDITIONAL EXPERIMENTS, FOR HOME OR SCHOOL

1. *A paper windmill.* Take a piece of paper about 6 inches square and fold it diagonally, i.e. from corner to corner. Cut half way across the folds as shown by the black lines. Now fold every other corner to the centre and push a pin through the middle. Make the pin-hole large enough for the windmill to turn on the pin.

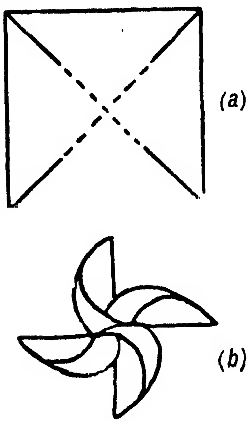


Fig. 39.

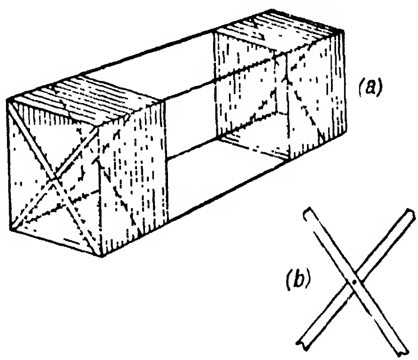


Fig. 40.

2. *A box kite.* This kite can be made from four light sticks 32 inches long. Two bracing cross-stays can be fastened across the ends, or, if made as shown in Fig. 40*b*, they can be glued in a little further as shown by the dotted lines in Fig. 40 *a*.

3. *A bird drinking fountain.* Fill a milk bottle with water and invert it into a small dish containing water. It is best to stand the bottle on one or two pieces of thin cork.

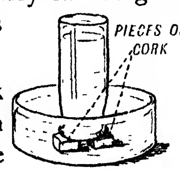


Fig. 41.

4. *How to make a good "sucker".* Take a circular piece of soft leather about 5 inches in diameter and screw it to a wooden

handle. Cut away some of the material just around the screw head. If such a "sucker" is properly fixed to the wall it will take an enormous force to remove it.

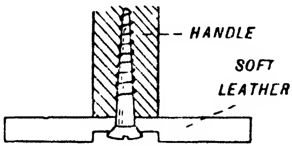


Fig 42.

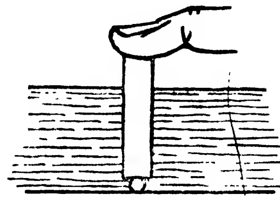


Fig. 43.

5. ***How to remove small animals or pieces of refuse from the aquarium.*** Place your finger lightly over one end of a piece of glass tubing. Lower the tube over the object required. Now remove your finger. Water will rush up the tube and carry the object with it. Trap the contents of the tube by replacing your finger and lift the tube vertically out of the tank.

6. ***How to make lime water.*** Shake up some lime with water (about one teaspoonful of lime to one pint of water is sufficient).

Allow the solution to stand for an hour or so and then pour off the clear liquid. This is lime water.

7. ***A model fire extinguisher.***

When it is necessary to use the fire extinguisher tilt it until the acid runs out on to the solution of washing soda. Then direct the jet towards the flames.

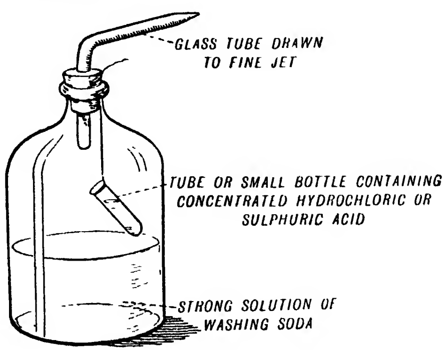


Fig. 44.

SECTION II. WATER

Chapter 3

OUR WATER SUPPLY

Introduction

Water is so plentiful in this country that we often fail to appreciate it. Nevertheless the supply of water to our houses is a matter of deep concern to those people (the water companies) responsible for its upkeep.

In country places the water is often obtained from springs and small streams or by boring wells, whilst in a few cases rain water is used. The towns obtain their water from rivers or lakes, mostly from the latter, and, in a few instances, by boring and making an artesian well.

Having selected a source from which to obtain water the water companies then busy themselves with the best method of conveying the water to our houses, and of making it fit for drinking and washing. Usually a lake high up in some hill is chosen and the water is conducted from it along pipes.

How the water is conveyed to our houses

Consider for a moment the apparatus shown in Fig. 45. If water is continually poured into *A* until it is full you will notice that the level of the water in the limb *B* is the same as that in *A*. Now if *B* is lowered to the position shown in 2 water will spurt out from it and shoot upwards until it almost reaches the level of the water in *A*. When *B* is lowered to the position shown in 3 the water shoots out with a greater force, and again will spurt upwards until it has almost attained the same level as of that in *A*. Because of this it is said that water always seeks its own level.

The difference between the levels of the water in limbs *A*

and B, h, as shown in Fig. 45, is known as ***the head of water.*** The greater the head of water the greater is the force of its pressure.

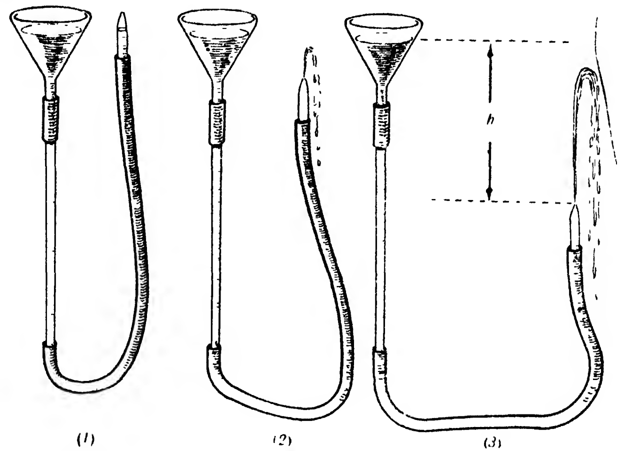


Fig 45.

Lakes chosen as a source of water are usually higher than the houses which they supply.

In Fig. 46 the force of water at house Y would be greater than that at house X.

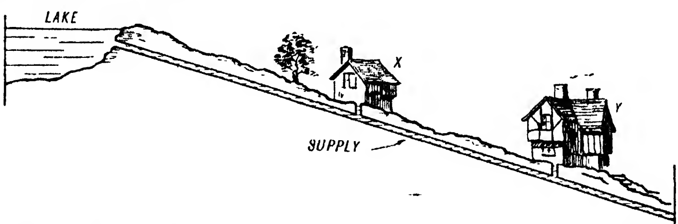


Fig. 46. Water descending from lake, to houses X and Y, along pipes.

Very often a lake supplying water is dammed. This raises its level and so increases the "head of water".

If the lake chosen has to supply a town situated on a neighbouring hill, then the water has to be pumped up into a storage

reservoir which has been raised above the level of the highest building in the town.

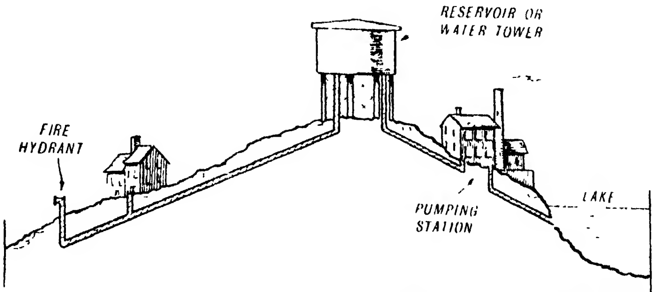


Fig. 47. Water being pumped up from lake to raised storage reservoir in order to obtain a sufficient head of pressure to supply water to houses at the same or higher level than that of the water in the lake.

Water obtained from artesian wells is pumped up into high reservoirs similar to that shown in Fig. 47 above.

Sometimes it is necessary to carry the water over a hill which is higher than the supply lake. The method of doing this will be understood if the apparatus in Fig. 48 is fixed up. The water can be transferred from the full vessel to the empty one by means of the glass or rubber tubing ***provided*** that this is first filled with water and the end *A* is lower than the level of the water in the higher vessel *B*. In this experiment the glass or rubber tubing is acting as a ***siphon,*** and the water is said to be siphoned from the one vessel to the other. Therefore, if the mains pipes taking the water from the lake to the houses, as shown in Fig. 49, are first filled

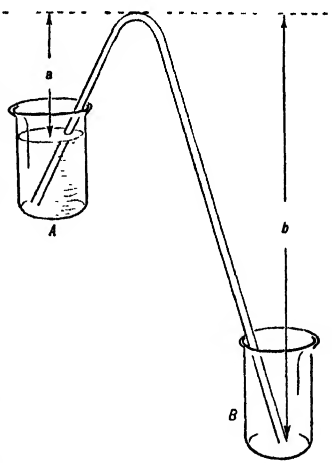


Fig. 48. Water being siphoned from upper to lower jar.

with water, then the supply from the lake will be siphoned over the hill *A*.

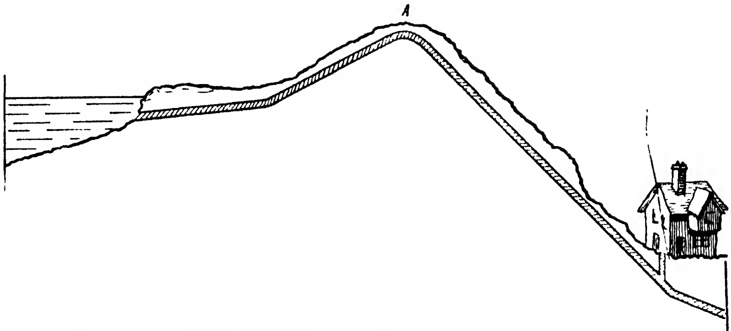


Fig. 49. Water being siphoned from lake over hill *A* to house.

How the siphon works

You will notice that the water at the top of the bend in the siphon (Fig. 48) is being pulled by two opposite or opposing columns of water of different lengths. The long column (*b*) exerts a greater pull than the short one (*a*), and so causes the water to flow in the direction of the arrow.

The artesian well

The sectional diagram shown in Fig. 50 depicts how a water supply may be obtained from under the ground. It shows a

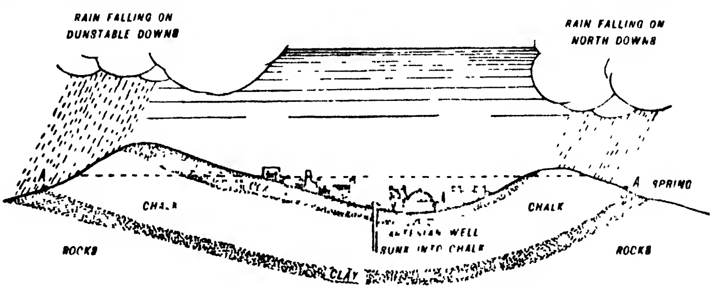


Fig. 50. A section showing how London's artesian well obtains its water. The dotted line has been drawn in to show the saturation level of the water in the chalk layer.

section of the earth's crust that lies below London and surrounding districts. You will see that this particular section is made up of layers of clay, chalk and rock; the layer or stratum of chalk being sandwiched between two of clay.

Rain falling on the Dunstable and North Downs soaks into the layer of chalk that lies below London, and in a rainy season this chalk stratum is saturated with water. A steel pipe has been sunk through the ground in the heart of London deep into the chalk, and water will rise in it almost to the level of the water saturated into the chalk, when the control tap is turned on.

Springs

Water that soaks into the chalk stratum will, under certain circumstances, appear again on the surface. Provided that the saturation level is higher than the points *A*, water will bubble out of the earth from these places (see Fig. 50) in the form of springs. This occurs because the water cannot soak deeper into the layer of clay.

The different kinds of water

All waters normally used for drinking contain impurities—some more than others. All contain dissolved air. Water that has been distilled is free from dissolved air or any other impurity.

Rain water is the purest of the natural waters, containing, however, a very large amount of dissolved air.

Waters obtained from granite or slate areas contain almost negligible amounts of impurities. Such waters are found in Loch Katrine and in Thirlmere, which are the sources of water supply for Glasgow and Manchester respectively.

Sand and rock waters contain a comparatively large amount of dissolved impurities. Chalk waters also contain dissolved impurities.

Hard and soft waters

The presence of dissolved air and small quantities of impurities often make water the more pleasant for drinking. Washing,

however, is made more difficult by them. The presence of impurities makes it hard to produce a lather and such waters are called ***hard waters***.

A lather is readily produced with rain water, which contains practically no impurity (apart from dissolved air which does not affect it) and is known as ***soft water***.

The serious disadvantages of hard water

You all know that before a lather can be obtained when washing in hard water a certain amount of soap is used up in getting rid of the impurities which form a kind of scum on the surface of the water.

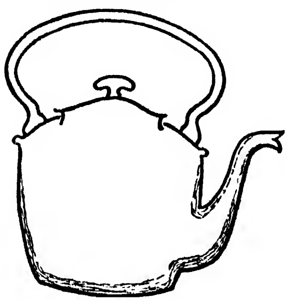


Fig. 51. A section of a "furred-up" kettle.

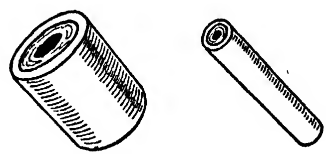


Fig. 52. Sections of "furred-up" pipes.

When Glasgow commenced obtaining its water from Loch Katrine instead of its old supply of harder water, it was calculated that almost £30,000 a year was saved to the city in soap alone.

Again, when hard water is boiled, some of the impurities—the chalk or limestone—are "thrown out" of the water and deposited on the sides of the vessel in which the water is being boiled. Look inside your kettle at home and you will find a yellowish white substance on the sides that, your mother will tell you, was not there when she purchased the kettle. She calls it ***fur***.

In the same way boilers used in factories and elsewhere become

lined with this hard substance known as ***boiler scale***. Boilers lined with this scale are more expensive to run as it requires more heat to raise the necessary steam. The uneven thickness of the scale also tends to produce uneven heating, which may cause the boiler to crack or even explode.

The removal of hardness from water

It will be seen from the previous paragraph that it becomes very necessary to remove as much of the hardness from water as is possible.

Almost all of this hardness is due to chalk or limestone dissolved in the water, and this can be removed by filtering the water through lime.

Distilled water

Perfectly pure water is made by distillation. This means that the impure water is heated until it changes to steam, the steam then being cooled until it condenses back into pure water. The impurities are left in the vessel containing the impure water.

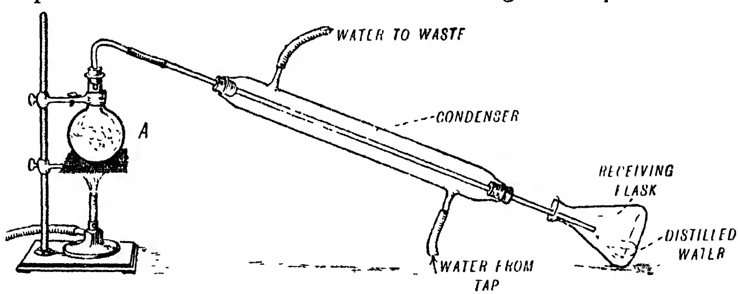


Fig. 53. The laboratory distilling apparatus.

In the science room distilled water is often made with the aid of the apparatus similar to that shown in Fig. 53. Water is heated in the flask *A* and the steam coming from it passes through the condenser, which is a kind of water-cooling jacket. The condenser cools the steam so that it condenses back to water, which is collected in the receiving flask.

When the water in flask *A* is first heated bubbles are noticed coming up through the water before it has begun to boil. These are bubbles of the dissolved air, heat having caused them to swell out or expand. The bubbles which form when the water is boiling vigorously are different; they are made of steam.

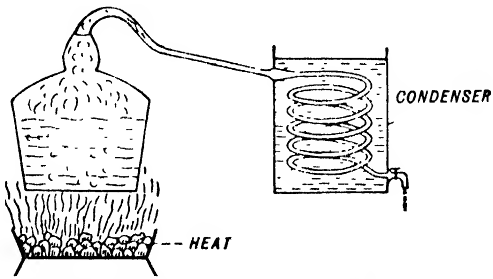


Fig. 54. A still used for distilling liquids on a large scale.

How to test for the hardness of water

Make up a solution of one-quarter of an ounce of soap to one pint of water. Now take a sample of rain water and add a thimbleful of soap solution at a time, shaking vigorously until you get a lather that will last for two or three minutes. Now take an equal volume of tap water (N.B. the vessels used must be clean every time) and repeat the experiment. If in the case of rain water two thimblefuls were used, and six were used in the case of tap water, then we know that the latter is three times as hard as the former.

How water is made fit for our use

Before water is fit to drink it has to have all the solid substances that we can see suspended in it, such as mud, removed. We call this filtering the water, and it is done by passing the water through sand gravity filters. Fig. 55 will explain how these filters work. The water issuing from the rough sand filter is then passed on to slow fine sand filters which remove the last remains of suspended matter from the water.

If the water is very hard after having passed through the sand filters, it is then passed through a filter bed of lime. (See paragraph on removal of hardness from water, page 43.)

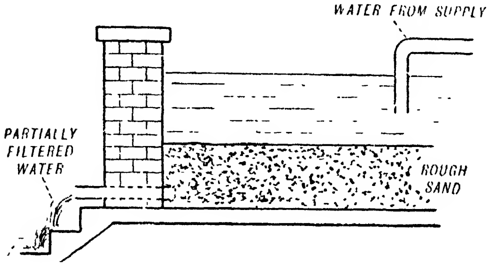


Fig 55.

Often chemicals in very small quantities are added to the water. These are to get rid of any impurity that may get past the filter beds. The purified water is then passed on to covered storage tanks.

How to make a simple filter bed

Take two glass quart-size bottles and remove their bases. Fit them with one-holed corks and join them together as shown in Fig. 56. Fill each of the bottles to a depth of 2 inches with clean

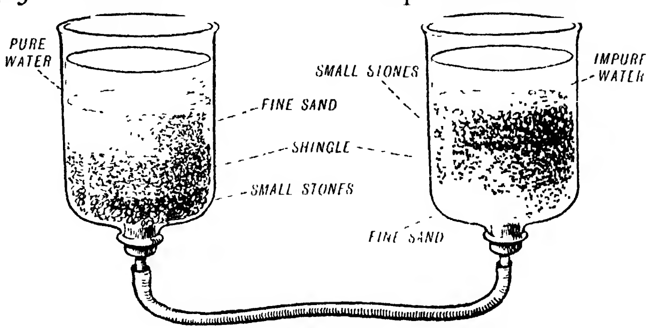


Fig. 56.

small stones, and then to a further depth of 2 inches with shingle. Finally, place 2 inches of fine sand on top of the shingle. Pour muddy water into the right-hand side of the apparatus. The water will pass through the filter and rise in the left-hand side in pure form. (Compare with Fig. 45.) The pure water can be siphoned off.

Filtering in the science room

Pieces of paper similar to blotting paper, and known as filter paper, are provided. They are first folded into half, and then

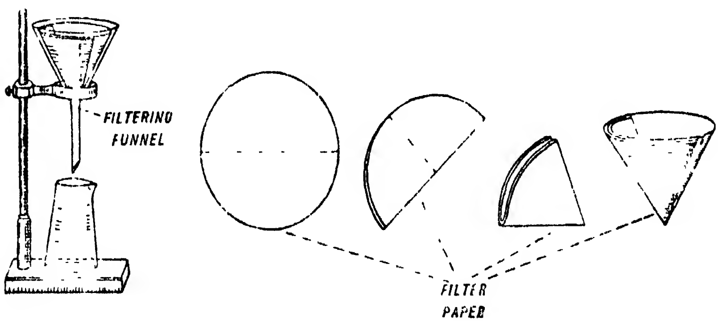


Fig. 57.

into the shape of a quadrant. The quadrant is then opened out into the shape of a cone with three thicknesses of paper on one side and one thickness on the other. If the cone is now placed into the filtering funnel, and a liquid containing suspended material, such as mud, is poured into it, the clear liquid will pass through the pores of the filter paper and be caught in the beaker below. The impurities, which are too large to pass through these pores, will be left behind.

Chapter 4

A. HOW THE WATER SUPPLY IN THE HOUSE IS CONTROLLED

Taps

The flow of water along the pipes in a house is controlled by taps and cisterns which are fitted with valves.

Fig. 58 illustrates how a tap is constructed. When the tap is turned off the leather washer is tightly screwed down over the hole through which the water has to come. Constant use wears this leather washer out. Difficulty in turning the water right off and subsequent leaking from the mouth of the tap indicate a worn-out washer.

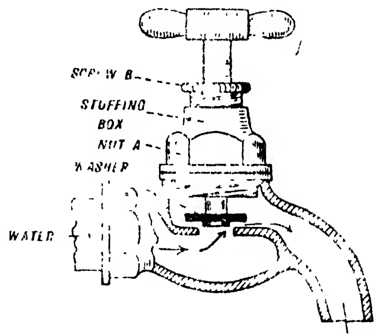


Fig. 58.

How new washers are fitted and leaks stopped

To fit a new washer to the tap the water supply to the house must be turned off. This is done by turning off the ***stop tap***, which is usually found under a small grating just outside the house. Then, with the aid of a spanner, the nut *A* (see Fig. 58) is undone and the old washer can be taken out and replaced by a new one.

When the tap is running leakage sometimes occurs through the stuffing box. If the screw *B* is removed the box will be found to contain greased cotton waste. When this is replaced by a fresh supply the stuffing-box leakage will cease.

The ball valve cistern

A sectional diagram of the ball valve cistern is shown in Fig. 59. It will be seen that the inflow of water to fill the cistern

is controlled by means of a float which, in reality, is a hollow copper ball. This copper ball rises with the water and shuts off the inflow when the tank is sufficiently full.

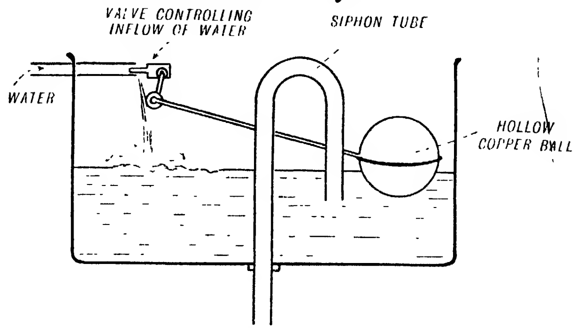


Fig. 59

As soon as the water rises up the short arm above the bend in the siphon tube all of it flows out by the long arm. This method of flushing is used in lavatories, but here the siphon is worked by hand as required. The pulling of the chain causes the water to be lifted above the bend in the siphon tube. See the paragraph *How the siphon works*, on page 40.

Drains

Pipes conveying waste matter from sinks and lavatories are always fitted with bends as shown in Figs. 60*a* and 60*b* below. When these sinks are flushed some of the water is trapped in the bends and this prevents the passage back of bad gases.

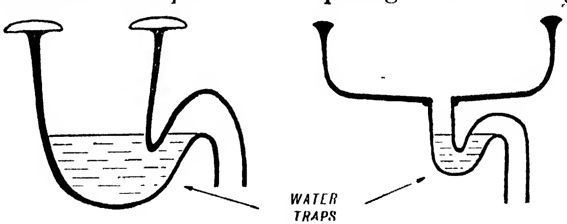


Fig. 60

B. THE NEVER-ENDING FRESH-WATER SUPPLY

The rain cycle

From where do the lakes and the rivers get their fresh supplies of water? This question has probably occurred to you several times when reading through these chapters on water. Although it would not be correct to say that the fresh supplies of water come from the sun, it is through the sun that the rivers and lakes obtain an almost continual supply of water. How? After there has been a shower of rain you have noticed how quickly wet

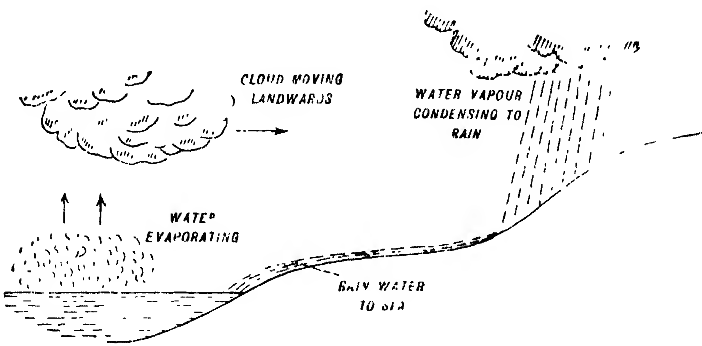


Fig. 61.

streets with their puddles dry up, particularly if the sun is shining on them. The heat from the sun has changed the water into an invisible gas, like steam from the kettle, called water vapour. This water vapour has mixed with the air and floated away. We say that the water has ***evaporated***. Now evaporation is always taking place from the surfaces of large stretches of water like the ocean, lakes and rivers. The vapour so formed rises in the air, and when it reaches colder regions forms what we call ***clouds***. Clouds thus formed over the sea are often carried by winds to the land. Here they, frequently, have to pass over hills and in doing so pass into higher and colder regions

—often so cold that the mist of the clouds changes into large drops of water which fall as rain. Much of the rain eventually finds its way into rivers. The rivers flow into the sea, and so the water arrives back from where it started.

Fig. 61 is an illustration of what we call the ***rain cycle.***

Why the sea is salt

The rivers flowing down to the sea carry with them all sorts of suspended material, such as mud and sand, and very minute quantities of dissolved material, mostly salts.

The river is slowed down at its mouth owing to the tides, and the suspended material sinks to the bottom and often builds up a bar or sandbank. The dissolved salts remain in the sea for all time, because when evaporation takes place only pure water vapour rises to make the clouds, for as you will remember all our rain water is quite "soft". When this pure water vapour drops as rain it will dissolve some more material, which will be carried down to the sea when the water has found its way into some river.

And so, year by year, the sea becomes more and more salty.

In some cases, especially those of land-locked seas, where evaporation is very rapid, and the inflowing rivers contain great quantities of dissolved material, the amount of salts in the water is enormous. Two outstanding cases of this kind are the Dead Sea of Palestine and the Salt Lake of Utah in America. There is so much salt dissolved in the waters of these inland seas that eggs and human beings cannot possibly sink in them.

The age of the earth

As the sea becomes more salty year by year, it is reasonable for us to assume that when the world first began the water of the oceans was as pure as that of our lakes.

Scientists have obtained an estimate of the amount of dissolved material in the oceans all over the world by taking samples from various seas and finding the average of the amount of dissolved

material in a unit volume, e.g. one gallon. This is then multiplied by the number of gallons of water estimated to be in the seas of the world.

By taking samples of water from the rivers of the world the scientists then estimated how much dissolved salts were brought down to the seas every year. From these two estimates it is possible to arrive at a rough idea of the age of the world—thus

$$\text{Age of earth} = \frac{\text{Amount of dissolved salts in oceans of world}}{\text{Amount of dissolved salts brought down by world's rivers yearly}}.$$

The answer runs into many millions of years.

Chapter 5

What is water?

Water, normally a liquid, is composed of two gases—Hydrogen and Oxygen—which are joined together chemically.

Some years ago two men, who had been experimenting with an electric battery, carelessly left the ends of the wires from it lying in a pool of water. They were astonished to see tiny bubbles of gas forming at the ends of the wires, and later collected this gas. They found that hydrogen was given off from the negative wire, and oxygen from the positive. There was twice as much hydrogen given off as oxygen.

What had actually happened was that the electric current had been tearing the water into its parts.

From this you will see that one part of water is made up of two parts of hydrogen to one part of oxygen. It is for this reason that chemists write H_2O as the formula for water.

You can do this experiment yourself by fixing up the apparatus shown in Fig. 62. The small medicine bottles or test tubes should be filled with water before inverting them over the blacklead terminals. N.B. The positive terminals of most batteries and

accumulators are either painted red or marked with a "plus" sign. That of a flashlamp battery is always the shorter brass strip.

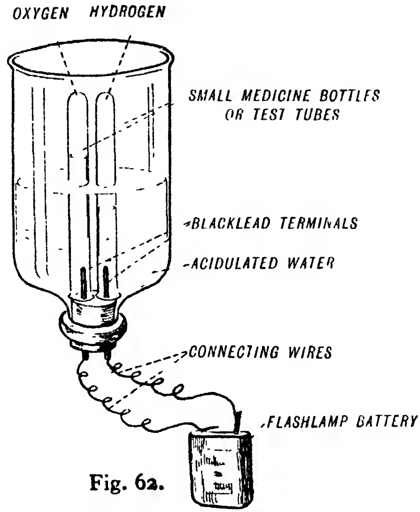


Fig. 62.

The experiment will go very much better if:

1. An accumulator is used in place of the flashlamp battery.

2. The blacklead is replaced by short pieces of platinum wire.

3. A little salt *or* acid is added to the water.

You already know how to test for oxygen, and so can prove that it is collected from the positive terminal. Now if you apply a match to the gas in the other container you will hear a slight "pop" or explosion and will notice that the gas burns with a blue flame. This shows that it is hydrogen that has been collected over the negative terminal.

How to make hydrogen

Most acids will give off hydrogen if a metal is added to them.

In the science room hydrogen is usually made by pouring dilute sulphuric acid on to granulated zinc in apparatus similar

to that shown in Fig. 63. If the hydrogen does not come off very quickly the action will be helped by the addition of a little copper sulphate.

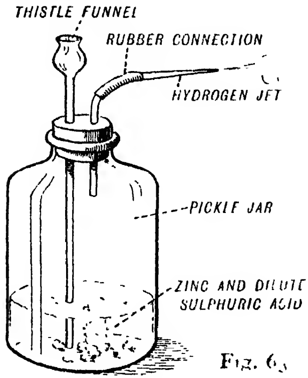


Fig. 63

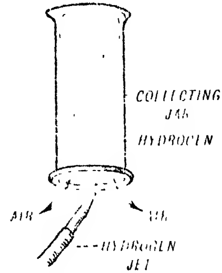


Fig. 64. Hydrogen is not visible. It has been drawn in, in figs. 63, 64 and 67, to show how it is given off.

The following equation will explain the chemical action that takes place in the pickle jar:

Dil. sulphuric acid + zinc = hydrogen + zinc sulphate (+ heat),

$$H_2SO_4 + Zn = H_2 + ZnSO_4 \quad (+ \text{heat}).$$

As hydrogen is very much lighter than air the gas may be collected by holding jars over the jet, as shown in Fig. 64, and then placing them mouth downwards on the bench.

The properties of hydrogen

If the hydrogen issuing from the jet is lit and the flame is allowed to play against the bottom of a cool flask, as shown in Fig. 65, drops of water will be formed on the side of the flask.

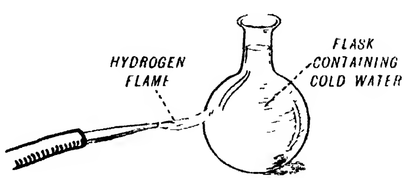


Fig. 65.

This water is formed by the hydrogen combining with the oxygen of the air whilst it is burning.

It is dangerous to light the hydrogen issuing from the jet until several jars have been collected previously. This is because hydrogen mixed with oxygen or air, which of course contains oxygen, is highly explosive.

What happened to the R 101

Hydrogen is such a light gas that it has been extensively used in the past for filling balloons and airships. This practice, how-

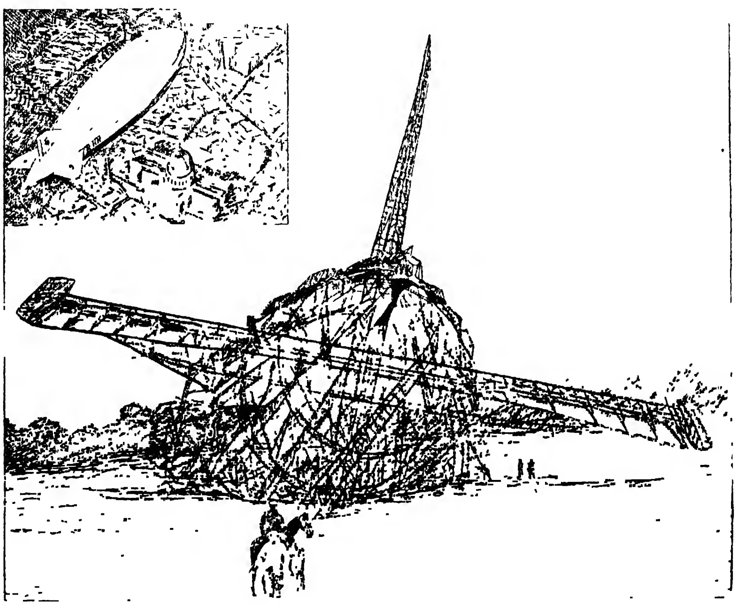


Fig. 66. The wreckage of the R 101 after the disaster at Beauvais. *Inset*—the R 101 flying over London.

ever, is extremely dangerous, owing to the explosive nature of the gas.

During the early part of the Great War German Zeppelins

filled with hydrogen were destroyed fairly easily by firing at them incendiary or fire bullets.

In 1930 a dreadful accident occurred to Britain's premier airship, the R 101, whilst it was passing over Beauvais in France. Inquiries that followed the accident showed that there had been a sudden loss of gas in the forward part of the ship which caused it to crash into rising ground. With hydrogen and oil as fuel the airship was completely burnt out and the majority of the passengers, including the Air Minister, were burnt to death in the ensuing conflagration.

Nowadays a non-explosive gas called helium, which is slightly heavier than hydrogen, is more often used for filling airships.

Below is the description of an experiment, which your teacher may perform for you, showing what would happen when the hydrogen of the R 101 caught fire. It is too dangerous for you to try on your own.

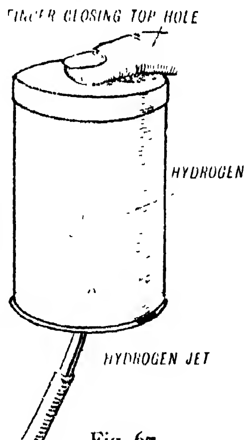


Fig. 67.

Take an ordinary cocoa tin and bore one hole in the centre of the lid one-eighth to a quarter of an inch in diameter, and another in the base of the tin about half an inch in diameter.

Now fill the tin with hydrogen by placing the bottom hole over the hydrogen jet (of Fig. 64) and closing the top one with a finger as in Fig. 67. Then place the tin on a tripod and with the aid of a long taper light the hydrogen issuing from the top hole.

The gas will burn away with its characteristic blue flame and air will enter through the bottom hole of the tin. When the air, hydrogen and flame meet a terrific explosion will take place which will blow off the lid.

Chapter 6

Water pressure

As is the case with air, water exerts a pressure in every direction and this pressure increases with depth. Water trickling through lock gates will illustrate this increase of pressure. The water finding its way through the bottom of the gate will probably spurt out to a distance of 2 or 3 feet, that coming through the middle will spurt out a much shorter distance, and water coming through towards the top of the gate will merely trickle out.

There is an experiment you can perform for yourselves to illustrate the increase of water pressure with depth. Take a tall tin can and up the side drill very small holes at intervals apart of 2 inches. Now cover the holes with your fingers and fill the can with water. When you uncover the holes jets of water will spray out as shown in Fig. 68.

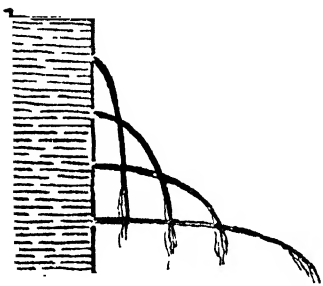


Fig. 68.

You will remember the account of Glaisher and Coxwell bleeding at the nose, ears, eyes and mouth because of the reduced air pressure when making their record balloon ascent. In the same way very deep-sea fish, whose bodies are so constructed to withstand the enormous pressure of deep water, often burst by that pressure being removed when they are caught and brought to the surface.

Why vessels made of iron float

When next you lie in your bath at home notice how difficult it is to keep your legs and feet on the bottom. They appear to be very much lighter in the water than out of it. What happens is that the water tries to press them to the top by a force known as the force of flotation.

A 14 lb. iron weight if weighed in water will only register approximately 12 lb. This apparent loss of weight is due to the upward thrust of the water, or the force of flotation, and is equal to the weight of water displaced by the volume of the 14 lb. of iron.

Fig. 69.

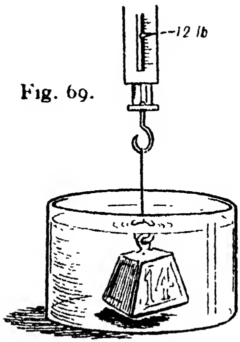
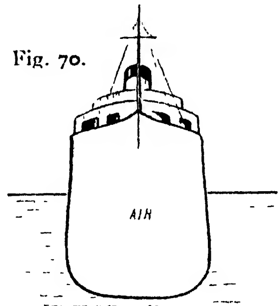


Fig. 70.



At the beginning of the nineteenth century people used to laugh at the idea of iron ships. Many thought that such vessels would sink.

The reason that an iron ship can float is that it is largely filled with air, so much so that the total weight of the submerged part of the ship and its contents is very much less than the upthrust of the water that the ship displaces.

Submarines

A submarine is an iron vessel which normally floats on the top of the water because of the large volume of air it contains. Most

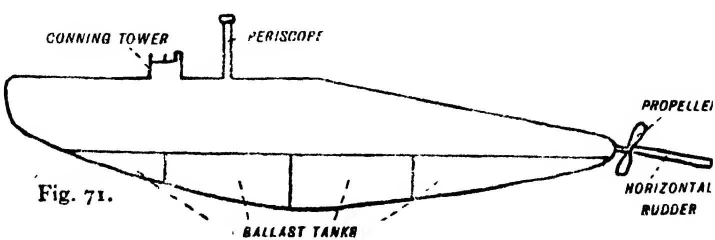


Fig. 71.

of the air keeping the submarine afloat is kept in the ballast tanks. When it is necessary to submerge the vessel these ballast tanks are allowed to fill with water, and when they are full the submarine is almost below water. It is made to go deeper by setting the ship in motion and turning its nose downwards with the aid of horizontal rudders. As soon as its engines are stopped the submarine will slowly rise to the top.

This is the reverse of the aeroplane, which falls to the ground when its engines are stopped.

Density

An iron ship floats higher in sea water than in fresh water as the upthrust of the former is greater than that of the latter. This is because the weight of a volume of sea water is greater than that of an equal volume of fresh water, owing to the salt dissolved in it.

Scientists have a much neater way of expressing this. They say either

1. Sea water is denser than fresh water, or

2. The ***density*** of sea water is greater than that of fresh water.

The density of any substance may be found by dividing its weight by its volume.

Thus $$\textit{density} = \frac{\textit{weight}}{\textit{volume}}.$$

N.B. To be strictly accurate the word "weight" should be replaced by "mass" (see Chapter 11).

Specific gravity

The specific gravity of a substance tells you how many times heavier or lighter than water that substance is.

Now the weight of 1 c.c. of water is 1 gm., therefore the density of water $= \frac{1 \text{ gm.}}{1 \text{ c.c.}} = 1$ gm. per c.c.

This shows you that specific gravity is numerically equal to density when the latter is expressed as gm. per c.c.

All substances with a density less than 1 gm. per c.c. will float in water. Those whose density is greater than that of water sink.

Hydrometers

The specific gravity of liquids, such as alcohols, wines and milk, can be obtained readily by placing in the liquids a kind of float called a ***hydrometer***.

These hydrometers, two of which are shown in Fig. 72, are made of glass weighted at the bottom to make them float upright. On the upper stems are marks to show the specific gravities of the liquids they float in.

The one on the left is a special hydrometer called a ***lactometer***. This is for testing milk. When put into pure milk it will float to the mark *M*. In pure water it will sink to the mark *W*. If it sinks to a point between *M* and *W* the milk is a mixture of milk and water.

In this way we are able to test the honesty of the milkman.

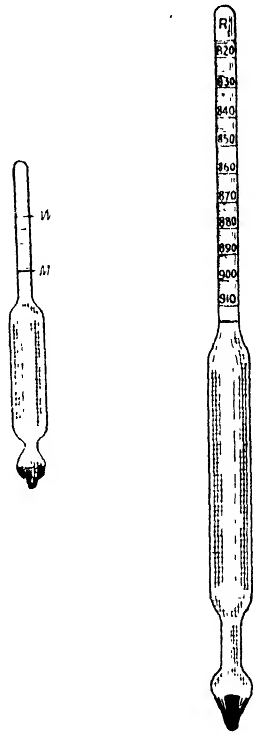


Fig. 72.

The Plimsoll Mark

A ship is really a huge hydrometer, for if you examine it when it is in dock you will observe some lines painted on the side similar to those shown in Fig. 73. These lines constitute the Plimsoll Mark and show the level below which, by law, the ship must not float when it has its full cargo aboard.

F.W. shows the level to be considered when the ship is in

fresh water. The other lines stand for the Indian Ocean in summer, and the sea in summer and winter respectively.

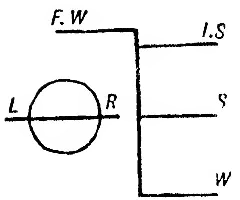


Fig. 73 *a*. The sign *LR* shows that the ship has been registered at Lloyd's shipping office.

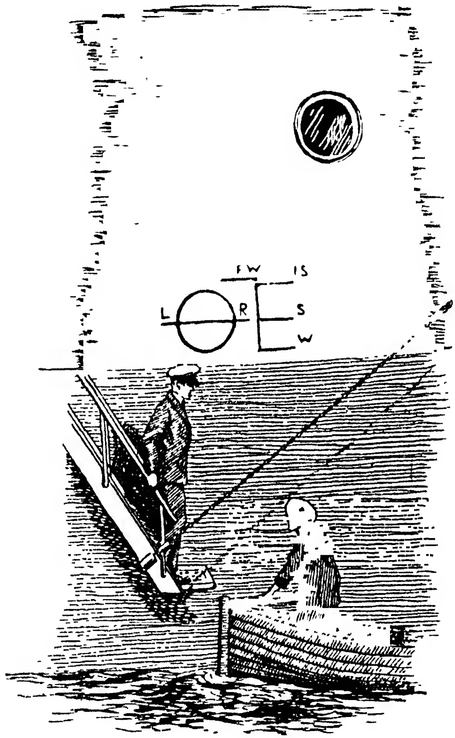


Fig. 73 *b*.

The legal adoption of these lines was the result of hard work by Samuel Plimsoll, M.P., almost fifty years ago. He introduced them to prevent the overloading of ships and the consequent endangering of sailors' lives when at sea.

Good and bad eggs

The density of a good egg is slightly greater than that of water, and if immersed in the latter will lie down, as shown in section 1 of Fig. 74.

In the large end of every egg there is an air space which daily becomes larger as the moisture in the egg evaporates through the porous shell and is replaced by air.

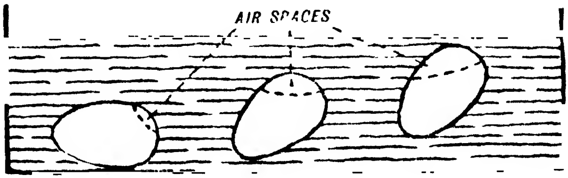


Fig. 74.

Thus stale eggs are very light and will either tilt at a steep angle or float when placed in water.

Eggs are often preserved by keeping them in a solution of water glass. The water glass fills up the pores of the eggshell and so prevents the moisture of the egg from escaping.

Summary

Water for drinking and washing purposes is obtained from lakes, rivers, wells, springs, or rain-water tanks.

If the water is to come through a tap in the house the level of the water supply must be higher than the tap. The height of this water level above the tap is known as the ***head of water***.

An ***artesian well*** consists of a tube sunk into a hole bored into the ground until it has reached a layer of porous earth, such as chalk. The water that has soaked into this layer or stratum rises in the tube to a height equal to its own saturation level in the earth. This is often above the upper end of the well.

Rain water has a lot of air dissolved in it. Water from lakes, rivers or wells contains dissolved air and very small quantities of other impurities, such as limestone. The more dissolved impurities (apart from air) there are in water the more difficult it

is to obtain a lather when washing in it. Such water is called ***hard water***. Rain water is ***soft water***.

The impurities contained in hard water cause "fur" or "scale" to form on the insides of boilers and kettles.

The hardness of water can be removed by passing it through lime.

Distilled water is made by boiling ordinary water until it evaporates and then cooling the steam that is formed.

A tap requires a new washer when there is difficulty in turning it right off. If a leak occurs at the stuffing box when the tap is running the contents of the box must be replaced.

Water traps are devices to prevent the passage back of bad gases along the pipes of sinks or W.C.s.

Water is made up of two parts of hydrogen to one part of oxygen.

Hydrogen can be made by pouring dilute hydrochloric or dilute sulphuric acid on to zinc. It is a very light gas, being between fourteen and fifteen times lighter than air. Hydrogen is highly explosive and inflammable when mixed with air.

Substances appear to weigh lighter when in water, because the water buoys them up with a force known as the ***force of flotation***.

Iron ships float because the weight of the ship and its contents —air, furniture, passengers and cargo—is less than the weight of an equal volume of water.

$$\text{The density of a substance} = \frac{\text{Weight of substance}}{\text{Its volume}}.$$

N.B. To be strictly accurate the word "weight" should be replaced by "mass". See Chapter 11.

The specific gravity of a substance tells how many times lighter or heavier than water the substance is. The specific gravities of liquids can be determined by floating in them instruments called hydrometers.

The Plimsoll Mark is a set of lines painted on the side of a ship to prevent it from being overloaded.

Questions

1. Describe (*a*) How water is supplied to a house from a high lake.
   (*b*) How water is supplied to a house from an artesian well or a lake which is situated at a lower level than the house.

2. What is a siphon? How does it work?

3. Describe (*a*) London's artesian well.
   (*b*) How springs are formed.

4. What is the difference between hard and soft water? What are the disadvantages of hard water and how can the hardness be removed?

5. How is distilled water made?

6. What is done to water before it reaches the tap to make it fit for our use?

7. (*a*) Make a sectional diagram of the tap and name its parts.
   (*b*) The tap can leak in two different places. What are the causes of these leaks and how are they cured?

8. Make diagrams of a ball valve cistern and a water trap. Say how each one works.

9. Draw a diagram illustrating how rivers and lakes obtain their fresh-water supplies.

10. Why is the sea salt?

11. Water is said to be made up of two parts of hydrogen to one part of oxygen. How would you prove this?

12. Say what you know about hydrogen.

13. (*a*) Why does an iron ship float in water?
    (*b*) Describe how the submarine works.

14. What is (*a*) density, (*b*) specific gravity? Say how you would find the density and specific gravity of any thing.

15. (*a*) What are hydrometers? For what purposes are they used?

(*b*) What is the Plimsoll Mark?

(*c*) How can you tell a good egg from a bad one?

Practical Work

A. TITLES OF EXPERIMENTS

The numbers given are those of the pages which will give you the necessary instructions.

The experiment printed in italics is intended for demonstration by the teacher. This is in order either to save time or because the experiment is dangerous.

1. To make a siphon and to show how it works. 39, 40. See also following additional experiments for glass bending.

2. To test distilled, rain and ordinary tap waters for hardness. 44.

N.B. A more accurate result will be obtained if soap solution is run into the water, a drop at a time, from a burette. See Chapter 12 for use of burette.

3. To show the effect of passing hard water through lime. Also Expt. 2 above.

Fix up the apparatus for filtering (Fig. 57) and place some lime inside the filter paper. Now pass some tap water through it. Test the filtered water for hardness as in Expt. 2 above.

4. To show what water is made of. 51, 52.

5. *To make hydrogen and to study its properties.* 52, 53.

6. To show that water pressure increases with depth. 56.

7. To show that objects seem lighter in water than in air. 57.

B. ADDITIONAL EXPERIMENTS, FOR HOME OR SCHOOL

1. Experiments with glass

(a) To cut glass tubing. Draw a triangular file quickly but not heavily across the tube where the cut is required. Take the tube in both hands with the thumbs meeting beneath the scratch. Now bend the thumbs inwards. If the tube does not break easily make the scratch a little deeper and longer.

(b) To bend glass tubing. Rotate the tubing in the bats-wing burner as shown. When the glass is sufficiently soft you may bend it as required.

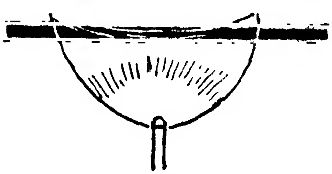


Fig. 75.

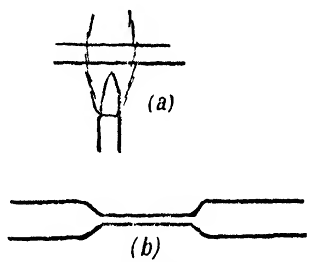


Fig. 76.

(c) To make a fine jet. Hold a piece of tubing just above the blue cone in the non-luminous Bunsen burner flame and keep rotating it. When the glass is quite soft remove it from the flame and pull at either end. The more rapidly you pull the finer the tube will be. Two jets will be made by breaking the fine tube in two.

(d) To seal a glass tube and blow a bulb. Rotate the end of the tube in the non-luminous Bunsen burner flame. The sharp edges will become rounded and then gradually close together. To obtain a bulb continue rotating and heating the tube until a small quantity of molten glass is formed. Then remove it from the flame and blow down the open end.

2. ***A home-made fountain.*** Fit up the apparatus shown and tie the pot to the wall to prevent it from toppling off the shelf. The distance *h* represents the ***head of water***. The greater the

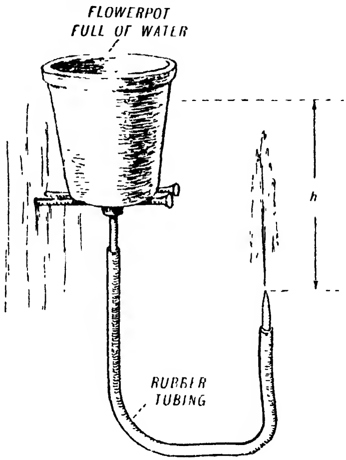


Fig. 77.

head of water the greater will be the force of water coming from the jet. If the jet of water is fairly powerful it will support a table tennis ball.

3. ***The siphon and how it may be used for supplying air to the aquarium***

The siphon can be of rubber tubing if necessary. It must always be filled with water before it will work. If the apparatus

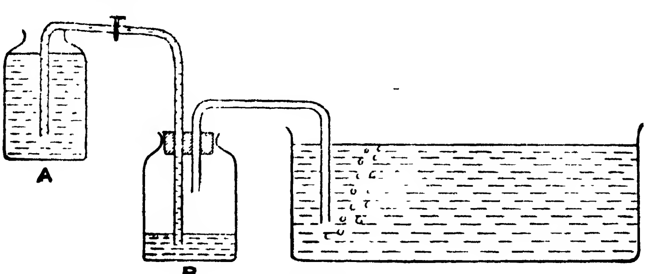


Fig. 78.

is arranged as shown above and the clip is fixed so that water slowly passes through the siphon from bottle *A* to bottle *B*, then air will be forced out of *B* into the water of the aquarium.

4. *How to make your own still*

The distiller can be made from a tin with a press-in type of lid. If the seams leak they must be soldered. The condenser can be made from a piece of piping open at both ends.

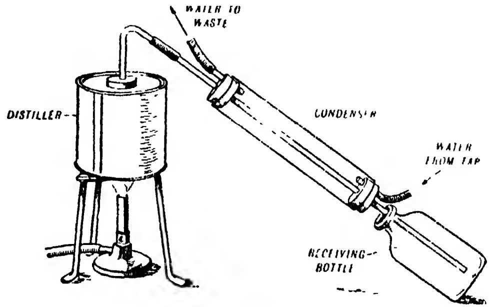


Fig. 79.

5. ***Filtering solutions.*** Make a filter bed similar to that shown on page 45. Try and filter some salt water through it. Taste the filtered liquid. Can you explain what has happened?

6. ***To remove salt from salt water.*** Put your salt water into some vessel that will stand heat. Heat it until all the water has changed to steam. What are you left with? When cool taste it.

7. ***The tap.*** Turn off the water stop tap to your house at a convenient time and then take one of the house taps to pieces. Examine the washer and from some new shoe-mending leather cut several more washers. Put them by for future use.

8. ***A self-emptying cup.*** With the aid of the batswing burner bend a piece of glass tubing into the shape shown in Fig. 80. Now bore a hole in the bottom of a treacle tin sufficiently large to take a cork through which the glass tube will pass. If the tin is now held under a running tap, it will fill until the level *ab*

is reached and then will run out through the glass tube until the level *cd* is reached.

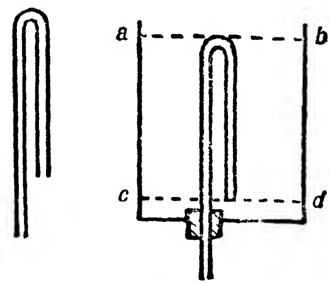


Fig. 80.

9. ***A can that is self-filling.*** Fig. 81 shows the diagram of a can with a hole half an inch in diameter bored in the bottom of it. On the top of this hole is a marble. If the can is lowered into a bucket of water, the water will enter the tin by pushing past the marble. When the can is lifted out the marble is held firmly against the hole and so the water cannot escape.

10. ***How to make your own hydrometer.*** Paste a piece of paper marked off in tenths of an inch inside a test tube. Put lead shot into it until the tube floats upright in water. Now drop some melted candle fat inside the tube to keep the lead shot in position.

Float your hydrometer in different liquids and note the reading for each.

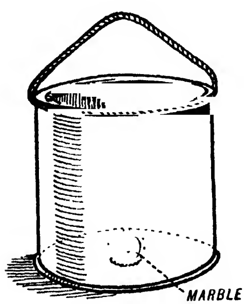


Fig. 81.

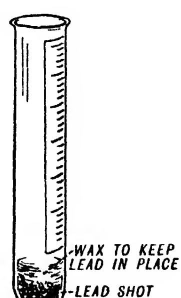


Fig. 82.

Section III. LIVING THINGS

Chapter 7

PLANTS AND ANIMALS

So far we have been reading about non-living things, or things that have never lived. We speak of a dead cat as being "dead", not "non-living", because it was once alive. In this Section we shall learn something about living things. The study of living things is called ***biology***.

If you are asked for the names of living things, you will probably say, cows, horses, sheep, birds, fish, butterflies, etc. You may perhaps think that only those things which move from place to place are alive. This is not true; plants such as the green scum on ponds, sea weeds, moss, ferns, flowers and trees, even when they appear dead in the winter, are alive. All living things are either plants or animals.

Differences between living and non-living things

Living things have a number of characteristics, or chief features, by which we can tell them from non-living things.

1. Living things ***feed***. The food taken in is changed into different substances in the animal or plant, before it actually becomes part of the body. You all know that if you roll a snowball down a snow-covered hillside, it increases in size by adding more snow to its surface. A child does not grow by adding pieces of bread, meat or potato on to its body, but by eating food. This food is changed in the body into muscle, nerve, bone, blood, etc.

2. All living things ***breathe***, although the breathing cannot always be seen, as, for instance, in worms and plants (see Books II and III for animal and plant breathing).

3. Living things can ***reproduce***, that is, they produce others like themselves. A cat has kittens, and plants have seeds which grow into new plants. If you put a number of mice together in a cage and the same number of stones and count them at the end of twelve months, you will find that you have more mice than you started with, but you have the same number of stones. This shows that living things reproduce, but non-living things cannot. All living things are produced by living things. People used to think that food went mouldy just because it was damp, and that maggots were formed by meat that was not good. Now we know that things will not go mouldy if kept airtight, and maggots are not found on meat unless we let flies lay eggs on it.

4. Living things are affected by what there is around them. All of us can see, hear, smell, taste and feel. These are called our ***senses***. All animals have some or all of these senses. If a mouse sees or hears a cat coming towards it, the mouse darts down its hole. If you smell some tasty food, extra juice (called saliva) comes at once into your mouth. You shudder when you drink nasty-tasting medicine, and if someone sticks a pin into your arm you immediately jump. Whatever causes any such change

Fig. 83. Leaves of Clover in the day and night positions.

in animals is called a ***stimulus***. Plants also change when stimulated. When a runner bean touches a stick, it twines round it. Shoots always grow towards the light, and some plants open only in the light, for example, clover leaves (Fig. 83) and daisy flowers. Roots grow downwards as a result of gravity (see Chapter 11). If your mother buys flowers, or picks them out of the garden, and puts them into a vase in a hot room, they are

soon wide open. Plants, then, are affected by touch, light, gravity and heat.

Differences between plants and animals

Most children think that all animals can move from place to place, while all plants are fixed in the soil. This is almost true, but there are a few tiny plants in water which move about, and there are some animals, such as the coral (Fig. 84) and the oyster, which do not.

Fig. 84 A piece of Red Coral showing animals partly embedded in the calcium carbonate shell.

There are three chief differences between animals and plants.

1. They require different kinds of *food*. Plants feed on the carbon dioxide gas in the air, with the help of the green substance in their leaves (see Book III). Their roots take in water and salts, such as nitrates, sulphates, phosphates of potassium, calcium, magnesium and iron. The farmer manures his ground to replace these salts, which have been used up by the plants. These substances are changed in the plants into more complicated compounds.

The food of animals, however, is partly made up of very complicated compounds which they obtain from plants, either by eating plants, or by eating other animals which feed on plants. For instance, we may eat vegetables, fruits, etc., or meat, such as beef, that we get from cattle, which in turn feed on grass. If you think of all the things that you eat, you will find that we depend entirely on plants for our food. "All flesh is grass."

Since animals have to seek their food, they must move, and so they have muscles, nerves, and a brain. Since their food consists of complicated foods they have special organs to digest it.

2. The living parts of all animals and plants are made up of a jelly-like substance called ***protoplasm***. The living substance is sometimes hardened by minerals, as, for example, in bone. A baby's bones are very soft and gristle-like, and gradually they become hardened by minerals.

In all plants and animals that we shall study (except the Amoeba) the protoplasm is divided up into very small compartments called ***cells***. These can only be seen with a microscope. Plant cells differ from those of animals, as the former are surrounded by a wall of dead substance, called the cell wall. Plant cells have rigid walls, whereas animal cells do not.

3. The body of an animal usually has a ***definite size and shape***, whereas a plant branches in all directions, so that its shape is constantly changing. Compare a horse with a tree.

Chapter 8

SOME SIMPLE ANIMALS

All animals can be placed in one of two large groups:

1. Animals with backbones: these are constructed more or less like ourselves.

2. Animals without backbones: these are quite unlike us.

By considering just one thing, we can tell into which of these two groups any animal should be put. Every animal with a backbone has a skeleton consisting of bones, which make the body rigid (see Book III). Backboneless animals, on the other hand, have no bones, although some have a hard outer covering which makes the body rigid, for example, the shell of a Beetle or of a Crayfish (Fig. 92).

In this book we shall learn something about the backboneless animals, leaving those with backbones until Books II and III.

The Amoeba

The Amoeba (Fig. 85) is a very tiny animal, about one-fiftieth of an inch across, which is found in the mud at the bottom of ponds. (If you have a microscope in your school, your teacher will show you an Amoeba, as you cannot see it with your naked eye.) It looks like a small piece of soft colourless jelly which is always changing its shape. It is not divided up into cells.

MOVEMENT. When the Amoeba moves, its soft jelly-like substance, which is protoplasm, bulges out on one side, then the remainder flows after it in the same direction.

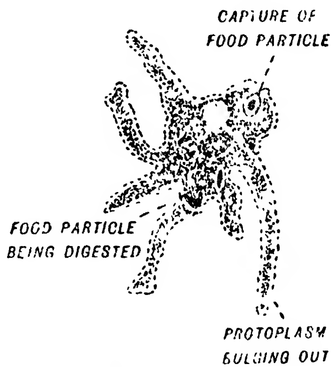


Fig. 85. Amoeba.

FEEDING. If an Amoeba meets a plant smaller than itself, the protoplasm of the Amoeba flows round the plant. So the Amoeba's food becomes surrounded by a drop of water inside the animal (Fig. 85). The plant is then digested, that is, changed into a substance which will dissolve in water (see Book III). This is done by a solution which passes into the drop of water from the protoplasm. The digested food next passes from the drop into the protoplasm. The animal then flows away from that part of the food which was not digested and leaves it behind.

BREATHING. We cannot see the Amoeba breathing, but oxygen, dissolved in the water, passes into its body, and carbon dioxide

passes out again, over the whole surface of the animal (page 28).

REPRODUCTION. When an Amoeba is fully grown, it divides into two (Fig. 86). Two daughter Amoebae are thus formed, and there is no parent left to die of old age. When larger animals than Amoeba are growing, the cells of which they are made divide in this same way, but the daughter cells remain together instead of separating from one another.

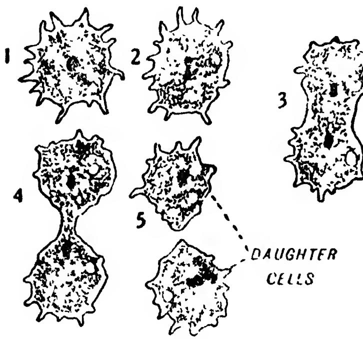


Fig. 86. Amoeba dividing.

Although the Amoeba consists of only one cell, we have learned that this cell can move, feed, breathe, get rid of waste matter, reproduce. It will even move away if a drop of acid is put into the water.

SIMILAR ANIMALS CAUSING DISEASE. You have probably heard of people having sleeping sickness, malaria fever, or dysentery, which is a very bad form of diarrhoea. These diseases are caused by small Amoeba-like animals in the blood. In Chapter 10 you will learn how these animals get into our blood.

The Hydra

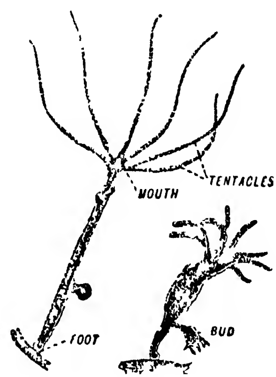


Fig. 87. Complete Hydra. The animal on the left is fully extended, that on the right is half extended.

The Hydra is a small animal, usually about one-quarter of an inch in length, although it can stretch itself to more than twice that size, or shrink to a small lump (Fig. 87). Hydras are either brown or green in colour, and can be found fixed to the weeds in ponds. Next time you

go fishing, try to find some. They are very easy to see in a jar in school, but difficult to see in a pond, so you must bring some weeds to school. If you leave the weeds in a jar for a day without disturbing them, you may see some Hydras. These animals soon die if not properly cared for (see Appendix F).

If you live near the sea you can easily look at the Sea-anemone, instead of Hydra. It is very much like an enormous Hydra.

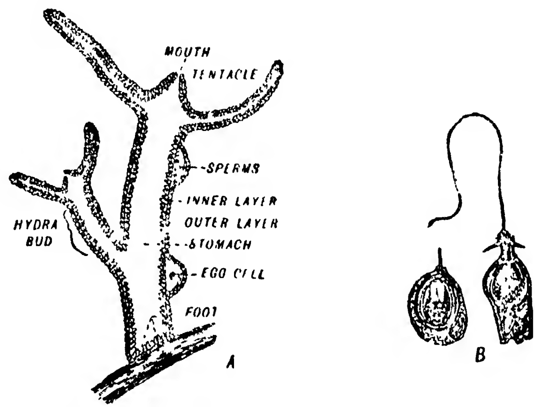


Fig. 88. *A*. Section of Hydra. *B*. Thread Cells. On the left the thread cell is coiled inside the cell: on the right the thread has been shot out.

A Hydra is usually attached at one end to a weed, called the ***foot***, whilst at the other end there is a ***mouth***, which leads into a space inside called the ***stomach***. Round the mouth are a number of fine threads, the ***tentacles*** (Fig. 88 *A*). These move about in the water, feeling if anything is near. If anything touches a tentacle, or if the water is disturbed, it immediately shortens up to the body.

MOVEMENT. A Hydra may stay in the same place for a long time. When it moves it slowly glides along on its foot.

FEEDING. On the tentacles are a number of ***thread cells*** (Fig. 88 *B*). These can only be seen through a microscope. When a tiny animal touches the "trigger" of a thread cell, out shoots the

thread, which is sticky and poisonous. Then the tentacles close over the numbed prey, which is drawn into the mouth, and then passed into the stomach, where it is digested. The stomach is really like a bag, surrounded by two layers of cells, and has only one opening which is the mouth (Fig. 88). Undigested food, therefore, has to be passed out through the mouth again.

BREATHING. The animal takes in oxygen, which is in solution in the water, and gives out carbon dioxide, over the whole surface of its body.

REPRODUCTION. If you can keep Hydra in your science room, you will find that they often have lumps on their bodies, which can easily be seen with the naked eye. The larger lumps are ***buds***. At the end of each bud a mouth and tentacles are formed. A wall then grows across the base, cutting the bud off from the parent. Then the young Hydra moves away and starts life by itself. A Hydra is very different from an Amoeba, because when it reproduces a parent is left behind, which will live for some time and later on will die, while its offspring continues alive.

The Hydra can reproduce in another way. You may see smaller lumps on the animal. In those nearer the foot, one large cell grows. This is an ***egg***, although it looks very different from a bird's egg (Fig. 88). In the lumps nearer the mouth, there are a larger number of tiny cells, which have a very strange shape (Fig. 89). They have a "head", in which is a nucleus, and a long "tail". These strange cells are called ***sperms***, and when the lump in which they are formed bursts, they swim vigorously in the water by means of their tails. If a sperm touches an egg, it joins with it, and then the egg can grow into a new Hydra. We say that the sperms ***fertilise*** the eggs. Only one sperm can fertilise one egg.

Fig. 89. Single sperm. Magnified 4000-fold.

If a Hydra is cut into two each part can grow again into a complete animal.

Corals

You can often see a Hydra with several buds on it. Imagine that, instead of becoming free, each bud grows to a full-sized Hydra, but remains attached to the parent. Then imagine that each of the buds, buds again, and so on until you have a small "colony" of animals, which seem to be branching almost like a tree (Fig. 84). Each animal of a coral colony makes or secretes a hard shell underneath itself of calcium carbonate (which is something like limestone); then of course it cannot move. After a time the animals die, leaving their shells, which are the Coral as we know it. Pink Coral is the most familiar kind, because we often see pink coral necklaces. The Great Barrier Reef of Australia, which is 1000 miles long and 50 miles wide, has been made by these tiny animals.

The Earthworm

Go into your garden and look for a worm. If it has been raining you will see worms on top of the ground. If it has been very dry, however, you will have to dig far down into the soil before you find one, because worms die if they are dry, and so remain far down in their burrows until the drought has passed.

Now look at your worm closely. Its body is made up of a number of rings or ***segments*** joined together. Let your worm move along, and you will see that it usually pushes its more pointed end forward. This is the ***head***, which has neither ears nor eyes like we have, but only a ***mouth***. If you hold your worm and look between the first two segments through a lens, you will see the mouth. On the last segment there is another opening, the ***anus***, through which the worm gets rid of waste matter (Fig. 90).

MOVEMENT. On each segment there are four pairs of ***bristles***, which you can feel if you rub your fingers along the worm. These give the worm a foothold as it moves along. It moves by pushing its head end forward, then drawing its tail up near to its head.

BREATHING. The worm breathes through its skin. The passing in of oxygen and passing out of carbon dioxide gas can only take place through living cells. The skin is kept damp by being covered with a slimy moist substance. This is important, because if the cells dried up they would die, and then the worm could not breathe.

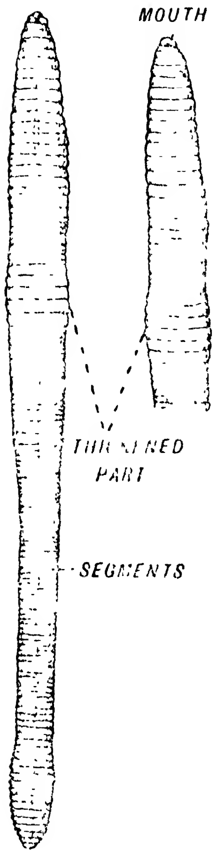


Fig. 90. Earthworm. Left figure from the upper side; right figure from the lower side.

FEEDING. Worms feed by eating the soil. The soil is passed into a "stomach", where the microbes which are in the soil, and which are the real food of the worm, are digested. The results of the digestion are then passed into the ***blood***. The digested food is carried to all parts of the body by the blood, which flows in vessels. The blood is coloured red like our own, and, besides carrying food, it carries oxygen from the skin to all parts of the body and carbon dioxide from the body to the skin.

Undigested food is not passed out through the mouth again, as in the case of the Hydra, but passes from the "stomach" along a tube until it reaches the anus, where it passes out. This is so in all animals more complicated in structure than the Hydra. The waste matter of the worm forms the coiled pieces of soil often seen on lawns. These are called ***worm casts***.

SENSES. A worm cannot see or hear, but it has ***nerves*** from its skin to its brain. With these it can feel the ground shake when an enemy is near, just as you can feel a heavy lorry shaking the ground as it passes by.

REPRODUCTION. A little way behind the head you will see a thickened part in all large worms. Round this part a case is

formed from time to time, into which the worm passes eggs and sperms; then it wriggles backwards out of the case. The ends of the case, or ***cocoon*** (as it is called), close up and, inside it, the sperms fertilise the eggs. These then grow into new worms.

If you accidentally cut a worm in two when gardening, it does not die. The head end can grow a new tail, but the tail end cannot grow a new head, so it dies. Do you remember what happens when a Hydra is cut in two?

USES OF WORMS. Worms make burrows in the soil, which are narrow tunnels ending in small round chambers. The worms are very useful to plants for a number of reasons. Air can pass down their burrows and so give oxygen to plant roots which always need it. Water can easily drain away down these spaces, and so prevent the soil from being waterlogged (see Book II). The soil which has passed through a worm's body is finely ground up, so the tiny root hairs of plants, which will be described later, can easily push their way through the soil. The worms also drag leaves into their burrows, thus manuring the soil.

Worms are very plentiful in soil, unless it is sandy and therefore too dry, but many are eaten by other animals, such as thrushes, blackbirds, toads, frogs, lizards.

Animals similar to the Earthworm

There are many different kinds of worms, living in all sorts of places, on land, in the water, or even inside other animals.

The Horse Leech is an example of a worm living in water, in ponds, streams or canals (Fig. 91). At each end of its body it has a sucker, by which it clings to any object. The mouth is in the middle of the front sucker. The Leech fastens itself to worms and water insects with this sucker, makes a small wound with its jaws, then sucks the blood, so gradually killing its prey.

Leeches something like the Horse Leech were at one time, and are occasionally nowadays, used by doctors to "bleed" patients suffering from certain diseases. In tropical forests leeches may attack men.

Some kinds of worms are often found inside larger animals, such as horses, dogs, etc., and are even found in human beings. The most common of these worms is the Threadworm, a small, white worm about half an inch long, very frequently found in children.

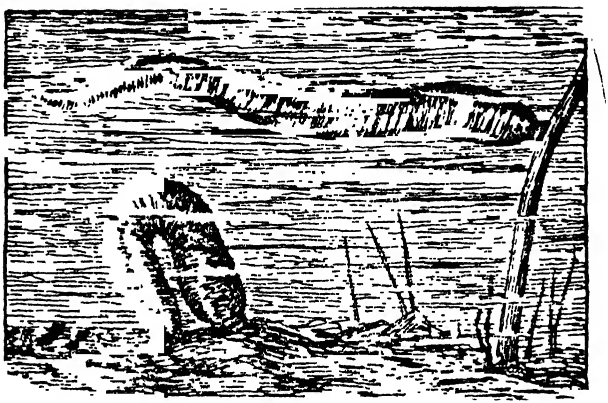


Fig. 91. The common Horse Leech.

Shrimps, Lobsters and Crabs

These animals, together with Prawns and Crayfishes, all belong to one group. You have seen most of them in a fish shop dead, but probably few of you have seen any of them alive. All these animals, except the Crayfish (Fig. 92), live in the sea, but the Crayfish lives in streams. There you will also find Fresh-water Shrimps, which are not quite like the Shrimps from the sea which you buy in shops.

All these animals have a hard shell covering them, to protect their bodies from other animals. Their colour is only reddish pink after they have been boiled. When they are alive, Lobsters are blue, Crabs are brown or green, while Shrimps are grey. They cannot grow in the same way as we do. Their shell cannot stretch, so from time to time it splits along the back, and the

animal wriggles out of it. Then the animal hides for several days, because its enemies could easily kill it and eat its soft body. Meanwhile it grows until its new shell which has formed hardens.

Most of these animals have eyes which are on stalks. They also have a large pair of claws for catching their prey, and four pairs of legs on which they walk (Crabs walk sideways). In addition, they have many other smaller "legs" which Shrimps and Prawns use for swimming while female Lobsters and Crayfishes carry their eggs stuck to them. They breathe through gills which are at the base of the walking legs.

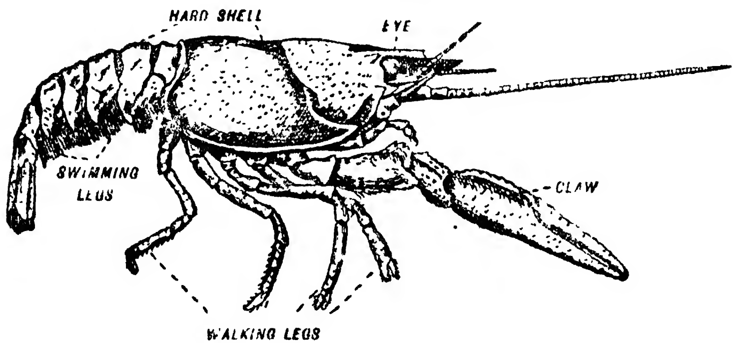


Fig. 92. Crayfish.

The Woodlouse, which is often found in houses and gardens, also belongs to this group. It carries its eggs in a pouch under its body and breathes through white gills under the end of its body. One kind can roll up to defend itself from enemies.

If these animals lose a claw or a leg, a new one can grow.

Spiders

All of you, I am sure, have seen a Spider, yet do you know how many legs it has? Insects, as you will learn later, have only six legs, whereas a Spider has eight, so a Spider is not an insect. At the end of each leg there is a jointed hook by means of which the Spider can run along the finest thread (Fig. 93).

Its body is divided into two parts, a small head and chest joined together, and a fatter, hinder part called the ***abdomen*** (Fig. 93).

The Spider has eight small eyes, yet it cannot see very well. It has, on its head, some strange jaws, which are like claws, and feelers. Poison passes down tubes into these jaws and out at their tips. A Spider wounds its prey with its jaws, and at the same time poisons it.

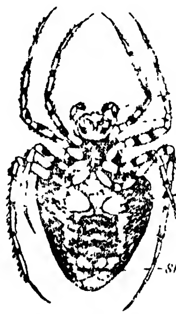


Fig. 93. Garden Spider. On the left, spider's foot enlarged.

THE WEB. One of the most interesting things about Spiders is the way they make their webs, which are really traps for catching their food. The webs are made of fine, silk threads. If you can find a large Spider, look underneath its abdomen with a lens and you will see six small lumps, called ***spinnerets***. Out of these comes a gummy liquid, which, as it dries in the air, forms a fine silken thread.

When spinning its web, the Spider first makes a framework of threads which looks like a wheel with spokes. This is fastened at four or five points to leaves or branches. If any thread is too loose, the Spider pulls it up with her claws. After this the spiral part of the web is woven, but now a sticky thread is used.

Some Spiders remain in the centre of their web until an insect is caught in it. Others, like the Garden Spider (which has a cross on its back), hide a little way away, with one foot touching

a silken thread which is fastened to the web. This is a "telegraph wire", for when an insect flies into the web, the web shakes and the thread is pulled. The Spider feels the pulling and knows that her next meal is ready. The Spider often kills insects larger than herself. She leaves her prey hanging by two threads, and turns it round and round, weaving a web around it so that it cannot move. Then she sucks its blood, or carries it into her "larder" (Fig. 94). Some Spiders do not make their webs in the form of a spiral, but weave numerous threads at random in all directions.

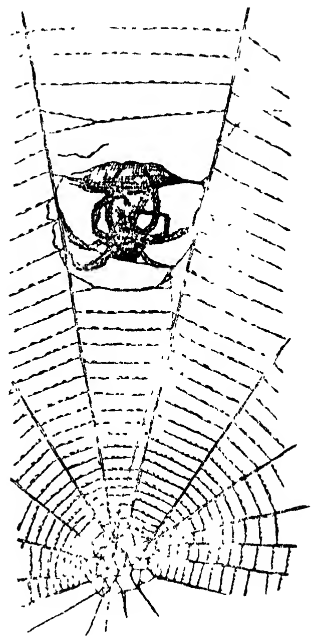


Fig. 94 A Spider wrapping silk round a victim.

There are other Spiders which make no webs but hunt their prey.

Reproduction. Male Spiders do not make webs of their own, but steal food from the female's web. The females are often larger than the males, and sometimes eat their husbands, although the latter may perform strange dances to gain their favour.

Females find a sheltered spot, and weave a silk case or cocoon, which is sometimes $\frac{3}{4}$ inch across, within which they lay about one hundred small, yellow eggs. These are laid in September. They may hatch out before the winter or not until the following spring.

Itch Mite

The Itch Mite also belongs to the Spider family. This small animal causes the disease called ***Scabies.*** The female burrows into the skin and makes small tunnels, in which she lays 20–30 eggs, and then dies. The young Mites crawl about on the skin, or in the clothes, and can easily find their way on to other people.

The Water Snail

The Water Snail belongs to a group of animals most of which have ***shells.*** These shells may be in one piece as in Snails, Periwinkles, Whelks and Limpets, or in two pieces hinged together, as in the Mussel (Fig. 95) and Oyster. Water Snails are the simplest to study because they can easily be kept in an aquarium (see Appendix F). They are found in ponds.

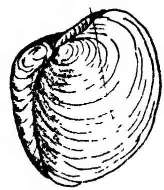


Fig. 95. Shell of Freshwater Mussel showing the two pieces of the shell.

Put a Water Snail in a glass jar full of water and look at it. Its shell is a spiral of six or seven turns, when fully grown. The oldest part is at the top. The shell protects the rest of the body, which is very soft. Only a large fleshy part called the ***foot***, and the ***head***, ever come out of the shell (Fig. 96). On the head you will see a pair of ***tentacles*** or feelers, two ***eyes*** on small lumps, and a ***mouth*** on the underside.

MOVEMENT. The Snail glides on its foot; it can even move along upside down on top of the water.

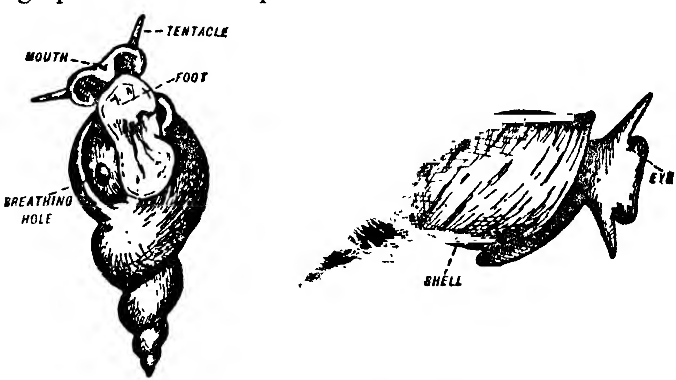


Fig. 96. Common Pond Snail.

FEEDING. Watch a Snail moving up the side of the aquarium, and you will see its mouth opening and closing, showing an orange speck. This is its ***tongue***, which has many rows of hard

teeth on it, and is like a file or rasp. The animal rasps away the weeds, or the green "scum" growing on the sides of the tank.

BREATHING. At the edge of the shell, on the right side of the Snail, you will see a hole. When a Snail wants to breathe, it comes to the surface of the water with this hole on top. Used-up air containing carbon dioxide gas is given out, and fresh air, which gives the animal the oxygen it needs, is taken in through the hole into a space or ***lung***. In the lung enough air is stored to last for some time while the Snail is under water.

REPRODUCTION. During the summer the Snail lays pieces of jelly on the weeds. These are about $\frac{1}{4}$ inch wide and $\frac{1}{2}$ to 1 inch long, and have twenty to thirty eggs in them. The young Snails hatch out of the eggs in about one month. They are fully grown in about two years, and may live for five years.

SNAILS AS FOOD. Land Snails are often eaten as food. French people breed Snails for this purpose. Relations of the Snail, such as Periwinkles, Whelks, Mussels and Oysters, are also eaten. The Oyster is fixed to one place like the Coral.

Pearl Oysters, chiefly found in the Pacific and Indian Oceans, are valuable because of pearls found inside them, and also for the mother-of-pearl lining the shell, which is used for making buttons and brooches. True pearls are formed by this kind of Oyster to protect itself against irritation due to very small sand grains which sometimes get inside it. The animal then makes (secretes) a pearl round the grain of sand.

SNAILS AND SLUGS ARE PESTS. Slugs are like Snails without a shell. Land Snails and Slugs do a lot of damage in kitchen and flower gardens, and also in fields, by eating young seedlings and potatoes.

Thrushes, frogs, toads, fowls and ducks will eat Slugs and Snails, so helping us to get rid of them. Repeated liming and sooting the ground also helps.

Chapter 9

FLOWERING PLANTS

You will probably be surprised to hear that all plants do not have flowers, but if you think of a Fern, for instance, you will remember that you have never seen it flower. Later on you will learn something about the plants that have no flowers.

Most flowering plants have similar parts, ***roots***, ***stems***, ***leaves*** and ***flowers***, each part having different uses for the plant.

The flower

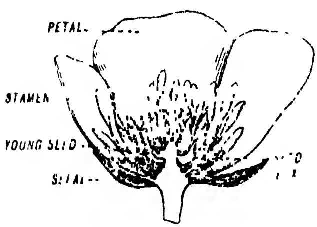


Fig. 97. Buttercup flower cut down the middle.

In the flower, seeds are produced which will later on grow into new plants. Almost all flowers have the same parts, though they may differ in colour, number and shape. If you get to know the parts of a Buttercup you can then compare any other flower with it.

The Buttercup

On the outside of the flower (Fig. 97) there are five green leaf-like parts called ***sepals***, which protect the flower when it is a bud.

Inside these are five yellow leaves called ***petals***, which in some flowers are joined together to form a tube, as in the Primrose (Fig. 97). At the base of each petal of the Buttercup is a swelling, where a juice called ***nectar*** is made, which bees turn into honey. Petals are usually brightly coloured to attract such insects.

The ***stamens*** are inside the petals. Each has a stalk and a swollen tip (the ***pollen box***) where ***pollen*** is made (Fig. 98). Pollen consists of fine grains like dust.

In the middle of each flower are a number of little green things called ***pistils***. The tip of each pistil is sticky when ripe. At the base of each pistil there is a ***seed box*** which contains one young seed. Some flowers, like the Primrose (Fig. 103), have only one pistil, the seed box of which contains many young seeds.

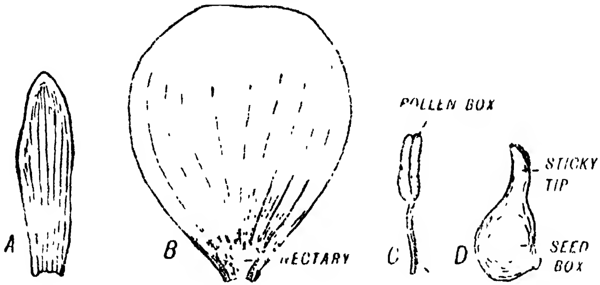


Fig. 98. Separated parts of a Buttercup flower. *A*. Sepal *B* Petal *C*. Stamen. *D* Pistil.

Pollination and fertilisation

Young seeds cannot grow into new plants unless some pollen reaches them. First the pollen must reach the pistil, that is, the flower must be ***pollinated***. From each grain of pollen that reaches the sticky end of the pistil, a tube grows down into the seed box. One of these tubes reaches the young seed (Fig. 99). The tube grows right into the young seed, where part of the pollen grain joins with part of the seed. This is called ***fertilisation***, and can be compared with fertilisation in the Hydra or the Earthworm.

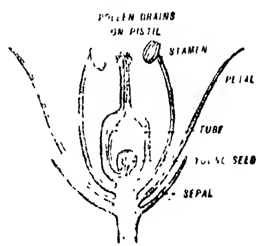


Fig. 99. A pollen grain fertilising a young seed.

Usually a flower is pollinated with the pollen from another flower, carried there by insects or by the wind. This is called ***cross-pollination***. If this does not happen, many flowers are

self-pollinated, that is, they pollinate themselves. Cross-pollination usually results in better seeds than self-pollination, and it is therefore to the advantage of a plant to be cross-pollinated.

Pollination by insects

Flowers pollinated by insects usually have bright colours and scent to attract these animals. The insects really come for the nectar, which is their food, and which they suck up with their "tongues". While they are collecting the nectar, pollen sticks to their hairy bodies. Later on, this comes off on the pistil tips of other flowers which they visit. Besides nectar, bees also gather pollen for their own use and carry it away as a lump stuck to each hind leg.

Many flowers provide a landing stage for the insects which visit them, for example the Dead-nettle, Snapdragon, Pea, Broom and Iris.

The Dead-nettle

This flower has five sepals, five petals joined together, one forming the landing stage and two others the "hood" (Fig. 100). Underneath the hood are four stamens, and a two-lobed pistil which sticks out below them.

A bee alights on the landing stage and pokes its head into the flower to get the nectar which is at the bottom of the tube of petals. The stamens, which ripen first, deposit their pollen on to the bee's back. If the bee then visits an older flower whose pistil is hanging below the stamens, the pollen is rubbed off the bee's back on to the sticky tip of the pistil. This is cross-pollination.

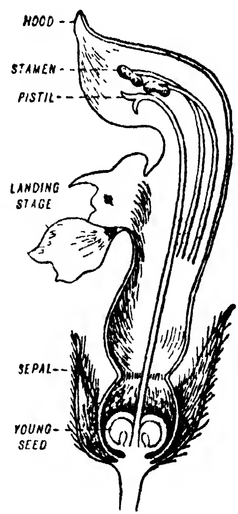


Fig. 100 White Dead-nettle cut vertically.

The Dandelion

The Dandelion is not one flower at all but hundreds of tiny flowers growing together forming the "head", which is surrounded by many tiny green scales. This is also true of the Daisy (Fig. 101), Sunflower and Burdock (Fig. 107).

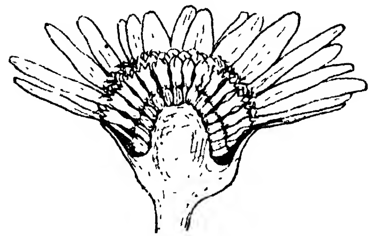


Fig 101. Flower head of a Daisy cut in two. The central flowers have short petals, those at the edge have three united petals drawn out into tongues

In the Daisy there are two kinds of flowers in the "head", but in the Dandelion the flowers are all similar. Each flower has hair-like sepals, five petals joined together to look like one, five stamens joined together by their pollen boxes, and one pistil whose tip is split in two when ripe.

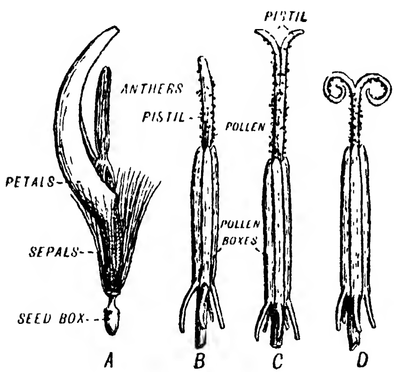


Fig. 102. Dandelion. *A*. Young flower. *B-D*. Stages in pollination.

The stamens ripen before the pistil, and shed their pollen inwards. This pollen is pushed out by the pistil as the latter grows. When the pistil is ripe, the two halves of its tip separate and become sticky. They are then ready to receive pollen brought from another flower by insects which crawl over the "head". If the flowers are not cross-pollinated by such insect visits, the halves of each pistil tip curve backwards and pick up pollen from their own styles. The style joins the pistil to the seedbox (Fig. 102).

Thus if the Dandelion cannot secure the advantage of cross-pollination with the help of insects, it falls back on self-pollination.

The Primrose

The Primrose has a wonderful arrangement for cross-pollination. There are two different kinds of flowers, ***pin-eyed*** and ***thrum-eyed*** (Fig. 103), each growing on different plants. In the pin-eyed flowers the tip of the pistil is at the top of the tube made by the petals, with the pollen boxes half-way down. In the thrum-eyed flower the opposite is true.

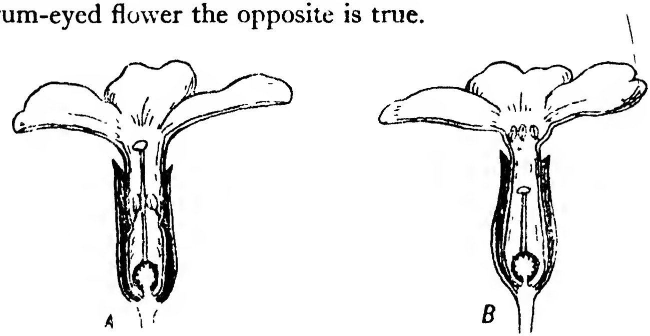


Fig. 103. Primrose. Pin-eyed (*A*) and thrum-eyed (*B*) flowers cut down the middle.

If an insect visits a pin-eyed flower to get the nectar from the bottom of the tube, pollen from the pollen boxes half-way down the tube gets stuck to the insect's head. When next the insect goes to a thrum-eyed flower, the pollen on its head is rubbed off on to the pistil of this flower. At the same time pollen from the pollen boxes of the thrum-eyed flower, which are at the top of the tube, gets on to the insect's body. This pollen is afterwards brushed on to the pistil of another pin-eyed flower.

The Willow

Willow flowers are also pollinated by insects. They have no brightly coloured petals, but they produce nectar to attract the insects. The pistils and stamens are found in different flowers growing on separate trees, which may be far apart. On each tree the flowers grow together in ***catkins***, the "Golden Willow"

having flowers with stamens, the "Pussy" or "Silver Willow" having flowers with pistils only. Look at single flowers of each kind, and compare them with Fig. 104.

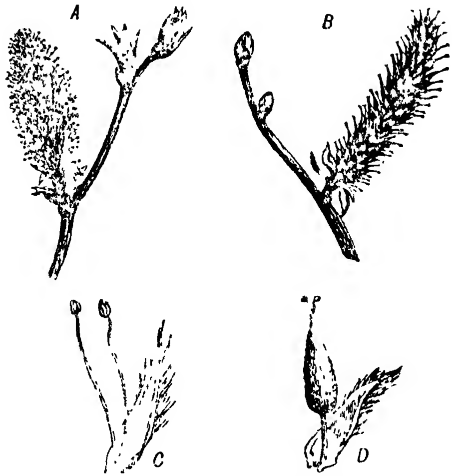


Fig. 104. Willow. A. Catkin of flowers bearing stamens B. Catkin of flowers bearing seed boxes. C. Flower with stamens. D. Flower with seed box. Each flower has a scale-like leaf to protect it.

Wind pollination

Flowers pollinated by wind do not need bright colours or scent, so that petals are often absent.

The stamens usually have long stalks, so that they readily blow about in the wind and scatter their pollen, which is very light. Pistils also are long and hang out of the flowers to catch the pollen.

Grass

Grass flowers are pollinated by wind. They are very small, so you must look at them through a lens. They have three hanging pollen boxes, and two feathery pistils at the top of the seed box,

which catch the pollen as it is blown about. There are no petals or sepals, only scales which look like tiny leaves (Fig. 105).

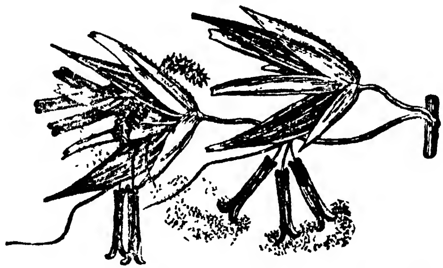


Fig. 105. Grass flowers with hanging pollen boxes and feathery pistils. Pollen is being blown from the right-hand flower on to the pistils of the left-hand flower.

Hazel

In the Hazel the pistils and stamens are found in different flowers on the same tree (Fig. 106), not on different trees as in the Willow. The flowers containing the stamens grow in catkins. Most people are familiar with the Hazel catkins, which when shaken give off a cloud of pollen.

On the same twigs you will see some green buds with red threads (really pistils) coming out of their tips. These buds contain the flowers with the pistils. Pull apart a single flower of each and compare them with Fig. 106.

When the wind blows, the catkins are shaken and pollen is blown about. Some of it will fall on these long red pistils.

Seeds and fruits

After the young seeds have been fertilised, the sepals, petals and stamens of the flower die. The seed boxes grow larger and larger and become the ***fruits***, inside which are the ***seeds***. Most people think a fruit is something juicy that we can eat, such as Plums, Apricots, Currants, Oranges, Melons. (A Marrow is also a juicy fruit although it is eaten as a vegetable.) The

word "fruit", however, means something more than this. Many flowers form hard fruits, like the nuts of the Hazel (Fig. 106)

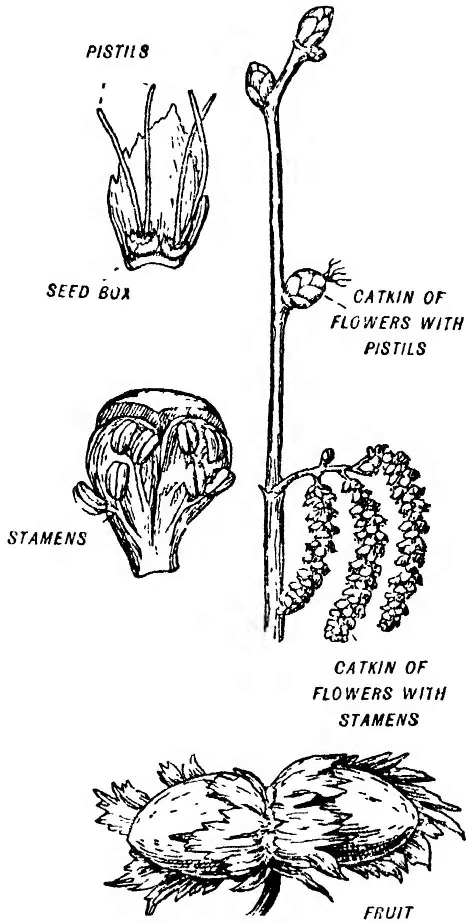


Fig. 106. Hazel.

and acorns. Pods, like those of Peas, Beans and Vetches (Fig. 109), are also fruits, but they are dry, not juicy. Inside these dry fruits are seeds.

Seed dispersal

When the seeds are ripe they must be scattered away from the parent plant. If not they will just fall on the ground beneath. In this case hundreds of young plants, called ***seedlings***, would grow so closely together, that they would not be able to feed, breathe or grow, and so would die.

So seeds must be scattered. ***Wind***, ***animals*** and ***water*** help to carry fruits and seeds away from the parent plant. In the case of some dry fruits, the seeds are shot out when the seed box bursts; these are called ***explosive fruits***.

Wind

Fruits scattered by wind are dry and very light. They either have "wings" (Sycamore, Lime, Fig. 107) or hairs (Dandelion, Fig. 107) attached to them, so that they easily float about in the wind. You have all blown at a Dandelion "head" to tell the time, so you know how well these fruits can float.

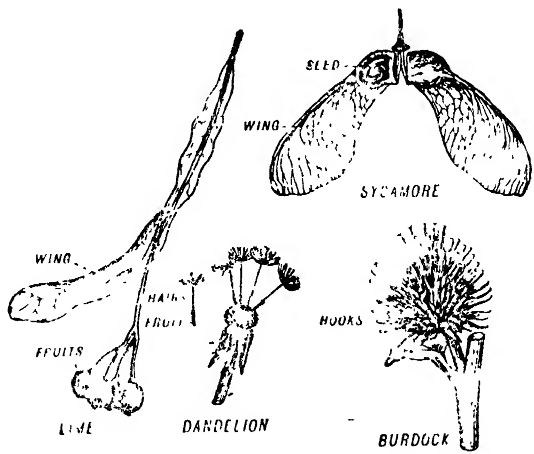


Fig. 107. Dry, non-splitting fruits.

Animals

Animals help in many ways to scatter seeds.

On the scales surrounding the dry fruits of Burdock there are

hooks, which cling to the coat of any passing animal, for instance a sheep, that touches them.

Squirrels whilst gathering and storing nuts for the winter may scatter them.

Some birds eat juicy berries like those on Hawthorn and Holly trees (Fig. 108). They either eat the juicy part and drop the seed, or they swallow the seeds, which pass unharmed through the bird's body. When a bird pecks one of the white berries of Mistletoe, which are sticky, the berry sticks to the bird's beak.

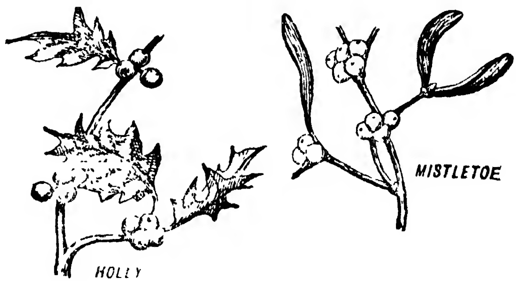


Fig. 108. Juicy fruits.

The bird cannot get rid of the seeds, so rubs its beak on the branch of a tree, thus rubbing off the seeds, which then begin growing on the branch. The young Mistletoe plant has no roots, so it sends a sucker into the branch to get some of its food. Since it lives thus on another living plant the Mistletoe is a ***parasite***.

Mud containing small seeds often sticks to the feet of birds, and is carried long distances.

Seeds of corn and edible fruit trees are, of course, often taken long distances by man and planted in other parts of the earth.

Water

Plants living in or near moving water have fruits which float. These may drop or be blown into the water, and may then be carried to other banks or shores. Coconut Palms are found near the sea shore in hot countries. (The coconuts bought in shops

are not complete, as the outer part which makes them float has been cut away.)

Explosive fruits

When the fruit is a dry one, its walls may split and shoot out the seeds, while the fruit is still joined to the plant. In the Gorse, Broom and Vetch (Fig. 109), for example, the pods dry and split in two. Each half curls up, forcing out the seeds some feet away. Sometimes the popping of the Gorse can be heard as the pods burst violently.

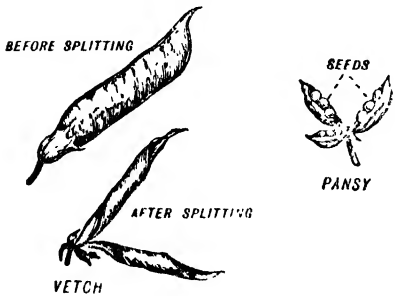


Fig. 109. Dry, splitting fruits.

The seed box of the Pansy is divided into three boat-shaped parts, which separate when the fruit is ripe (Fig. 109). The sides of each part in drying press on the seeds and shoot them out.

Structure of Bean seed

Before looking at a Bean seed, soak it for about a day in water; then it will be larger and softer.

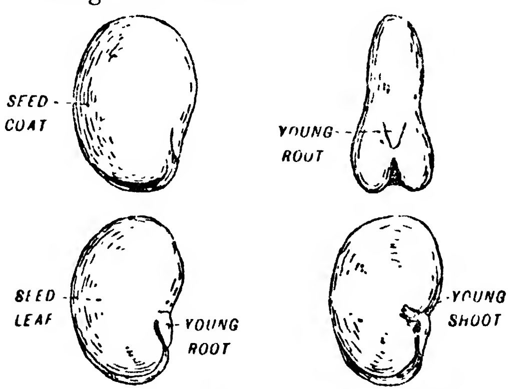


Fig. 110. Bean seeds. The bottom right-hand diagram shows the inside of the seed with one seed leaf removed.

A broad ***scar*** is seen at the thick end of the seed, where the seed was joined by a stalk to the pod (Fig. 110). Covering the seed is a thin ***seed coat***, which can be removed.

Inside the seed coat are two large fleshy ***seed leaves***, which can easily be separated. Where they are joined together there is a small pointed ***young root***, which can be seen through the seed coat, before it is removed. Between the seed leaves is a small bud, the ***young shoot***, consisting of a very small stem and folded leaves.

Germination

Usually a period of rest is necessary after seeds are formed before they will sprout or germinate. Most seeds wait through

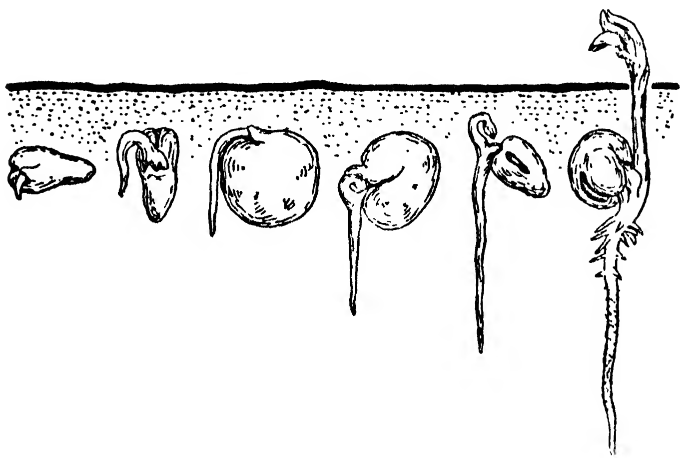


Fig. 111. Bean seed germinating. The young root grows downwards, and the young shoot upwards whatever position the seed may be in.

the winter and germinate in the spring. Many seeds are able to wait years before they sprout. Wheat and Barley will wait for ten or more years. Others, like the Poplar, only wait for a few weeks.

To find out how seeds grow we must watch them closely day by day. The easiest way to do this is to take a glass jar and line it with blotting paper. Moisten the blotting paper and place the

seeds half-way down the jar, between the glass and the blotting paper. Seeds often fall to the bottom of the jar if the blotting paper is not moistened before the seeds are put in the jar. Wet the blotting paper from time to time.

Germination of the Bean seed

When the Bean germinates, the seed coat splits and the young root grows downwards, no matter in which direction the seed may be lying (Fig. 111). Next the young shoot grows out, and then grows upwards. It is bent double as it pushes its way through the soil, so that the young leaves are not injured. When the young stem reaches the top of the soil, it straightens and its leaves turn green. Meanwhile the root has become longer and side roots have grown from it. All this time the young plant has been using the food in the seed leaves, which slowly shrink in size.

Germination of the Marrow Seed

When the Marrow seed germinates, the seed coat splits along its edges (Fig. 112) and the young root grows downwards. The root gradually grows longer and side roots grow from it. Meanwhile the young shoot grows upwards, bent as in the Bean, draw-

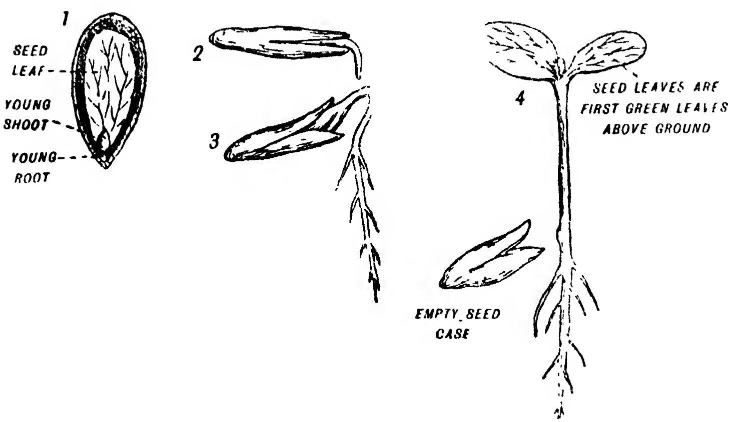


Fig. 112. Germination of Marrow seed.

ing the seed leaves with it. The seed leaves turn into the first green leaves above the ground. The empty seed case is all that remains of the seed in the soil.*

Fig. 113. Germinating Bean. 1. Root tip marked with ink lines 1 millimetre apart; 2. Same root 24 hours later.

Conditions necessary for germination

Under certain conditions seeds will not germinate very well, and may not even germinate at all (see Experiments, page 114).

During the winter, seeds will not grow because it is too cold. They begin to sprout when the warmer days of spring arrive. Seeds will not grow at a very high temperature either, but in this country such a temperature is seldom reached under natural conditions.

Water and oxygen are also necessary for germination, but most seeds germinate equally well in the light or in the dark (Expt. 31 page 114).

Region of growth of root and stem

As the root and shoot grow longer, the part behind the tip grows more quickly than the older part. This can be shown by marking lines, with cotton dipped in Indian ink, 1 millimetre apart, from the tip along the root of a seedling. After several days the marks immediately behind the tip are much farther apart than the others (Fig. 113).

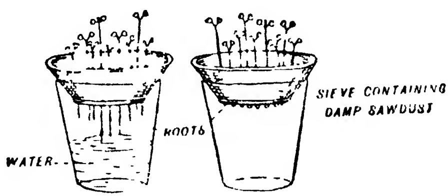


Fig. 114. Experiment to show that roots grow towards water.

* Refer to Book II, p. 119, fig. 127, for a comparison with the germination of the Maize.

Conditions affecting growth

TEMPERATURE has the same effect on growth as on germination.

GRAVITY. The fact that roots grow downwards is due to the force of gravity.

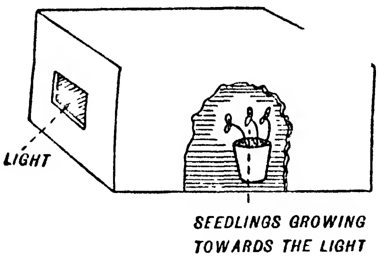


Fig. 115. Effect of light on direction of growth in plants.

LIGHT. Seeds grown in the dark at first grow as well as those in the light (see Experiments). After a time, however, you will see that the stems of plants growing in the dark are very long and weak. The leaves are yellow, as no green colour can be formed without light. Shoots always grow towards the light (see Experiments and Fig. 115).

WATER has a stronger effect on roots than gravity. Roots in the earth will turn from a dry part of the soil to one that is wet, even if they have to grow sideways (see Experiments and Fig. 114).

Chapter 10

INSECTS

The insects are a very large group of animals. There are nearly as many kinds of insects as of all other animals in the world.

The body of an insect is segmented, like that of the Earthworm, but in addition it is divided up into three parts. The ***head*** and the chest, or ***thorax***, are separate, not joined as in the Spider. The first one or two segments of the back part of the body, or ***abdomen***, are sometimes very narrow, forming a

"waist", as in the Wasp. On an insect's head there is a pair of jointed feelers, and two large eyes. On the thorax there are three pairs of legs and usually two pairs of wings (Fig. 117 *C*). In beetles the first pair of wings are hard, and in flies the second pair are missing. Some insects have no wings, for example the Stick Insect. Unlike Shrimps and Lobsters, insects have no limbs on the abdomen. There may be a sharp tube at the end of the abdomen for placing eggs where they are to hatch. For instance, Ichneumon flies lay their eggs inside caterpillars. Some insects, like the Wasp, have a sting at the end of their abdomen.

All adult insects breathe air, though in their younger stages they may live in water. Although living in water, some young insects nevertheless breathe in oxygen from the air, for example, gnats, whilst others take in oxygen from the water, in which case they have gills, for instance, the Caddis flies and May flies. All insects living on land have special openings on their bodies which lead into tubes. Air passes through the openings into these tubes, which then carry it to all parts of the body. This is a very different state of affairs from our own bodies, where oxygen is distributed by the blood.

Insects can taste and smell, and some can hear, particularly those which make noises. Grasshoppers chirp, not with the throat, but by rubbing their hind legs against their wings, and they have their ears in their abdomens.

The Cockroach

Cockroaches (Fig. 116) like warmth, so are found chiefly in houses, especially old ones, and even in bakeries. They feed on any animal or vegetable matter they can find.

The female has very tiny wings, useless for flight. The female lays eggs during the summer months, sixteen at a time. These are arranged in two rows inside a brown horny case, which the female carries at the end of her abdomen to a sheltered corner where she leaves it. When the young cock-

roaches hatch out they are like their parents but have no wings.

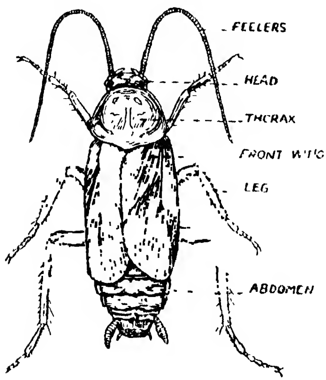


Fig. 116. Cockroach.

The wings begin to grow after twelve months. The insect is covered with a hard shell like that of the crayfish. This will not stretch, so, as the insect grows, the shell splits from time to time, and the young cockroach with its soft covering wriggles out. The animal swells and then its new shell hardens. The insect loses its skin, or ***moults***, seven times in the twelve months that it takes to grow.

Butterflies and Moths

Everyone who has kept silkworms or caterpillars knows that moths and butterflies start life in quite a different way from cockroaches.

One of the most common butterflies throughout the country is the Cabbage White (Fig. 117 *C*). This butterfly lays its eggs in May, or in July and August, on the lower side of cabbage and nasturtium leaves. Caterpillars, or ***larvae***, hatch out in seven to ten days and begin greedily eating the leaves. They moult from time to time until fully grown, and in colour are pale green with yellow stripes. The larvae of other butterflies and moths are very varied in colour and size. The caterpillar has six real legs on the thorax and several other stump-like legs on the abdomen called prolegs, with hooks on the tips. With these the caterpillar clings very firmly as it is climbing about (Fig. 117 *A*). In the middle of the lower lip of the mouth is a tube through which silk can be spun.

When fully grown, the caterpillar climbs up to a sheltered spot by making a silken ladder up which it climbs with its prolegs. Then it changes into a chrysalis, or ***pupa*** (Fig. 117 *B*),

which has a very hard covering. The pupa remains still and when touched can only move its abdomen. The caterpillars of some butterflies and moths weave a silken case, called a ***cocoon***, round themselves. Inside this they change to a pupa. It is the cocoon of the silkworm which is used for making silk.

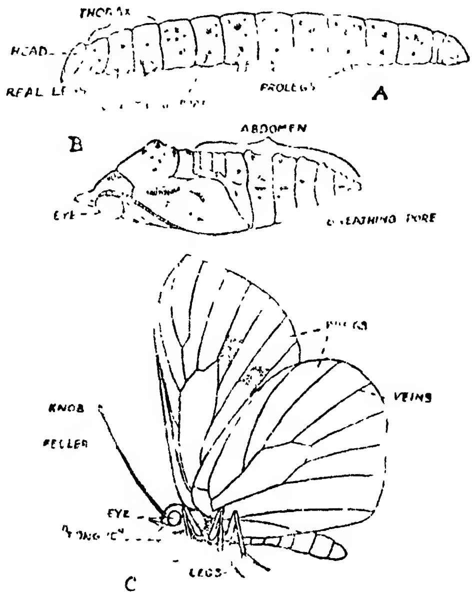


Fig. 117. Life history of the Cabbage Butterfly. *A*. Larva. *B*. Pupa. *C*. Adult.

If the pupae of the Cabbage White are from eggs laid in May, the adult insects come out of the pupa case in two or three weeks. If they are from the August brood they remain in the pupal stage throughout the next winter. The butterfly has six legs and two pairs of wings strengthened by so-called "veins". Its "tongue" is like a tube, up which it sucks nectar. It is very long and is curled up when not in use (Fig. 117 *C*).

The feelers of moths are generally more hairy than those of butterflies, which usually have a knob at the end of their feelers.

Flies

Flies lay their eggs on animal or vegetable matter which is decaying or "going bad" (Fig. 118 *a*). A female lays up to 150 eggs at a time, and may do so six times. From the eggs the white larvae, called ***maggots***, hatch out (Fig. 118 *b*). They feed on decaying matter. Horse manure is a favourite site. A maggot has no legs, and is pointed at the head end. At the hind end two breathing tubes open. Maggots do not like light.

When fully grown the maggot's skin turns hard and brown, and it changes into a motionless pupa (Fig. 118 *c*). Later on the adult fly comes out of the pupal case (Fig. 118 *d*).

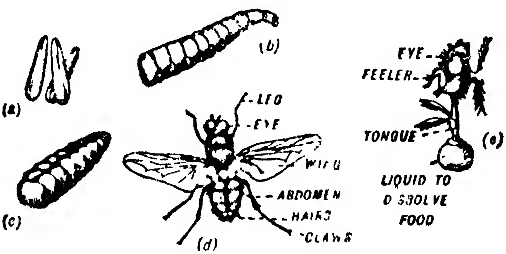


Fig. 118. Stages in life history of House fly. *a*. Eggs. *b*. Larva. *c*. Pupa. *d*. Adult Fly. *e*. Head of Fly.

In warm weather an egg will grow into a fly in nine to ten days, and a fortnight later the fly will be able to lay eggs. A fly's body is very hairy. It has two wings only. Each leg at its tip has hooks on either side of a pad which is sticky. This enables the fly to walk on the window pane, or on the ceiling. The fly has a "tongue" with which it sucks up liquids. When the fly is about to eat sugar, it first spits out a liquid which dissolves the sugar, and then it sucks up this sugar solution (Fig. 118 *e*).

Gnats

A Gnat is similar to the Mosquito. The male gnat has bushy feelers, and the female has not. Male gnats feed on the nectar of flowers, but the female stings other animals and draws blood from

the living prey. She does this by sticking a pointed tube into the skin of her prey, thus piercing the skin, and then squirting in a liquid which prevents the blood from clotting. Then she sucks up the blood.

The female lays her eggs in ponds, slow-running streams or water butts. She glues them together with a sticky stuff to form a "raft" (Fig. 119), which floats on the surface of the water. The larvae (Fig. 119) hatch out and feed on tiny green plants in the water. From the last segment but one of the larva there grows a tube, which is used for breathing. Although living in the water, the gnat larva gets its oxygen from the air by placing the end of the tube to the surface of the water. When the larva is swimming in the water this tube is closed by a valve. After several weeks the larva turns into a pupa which does not feed, but which can move about in the water. It has two breathing tubes on its head. The gnat finally comes out of the pupal case at the surface of the water, and flies away after its wings have hardened.

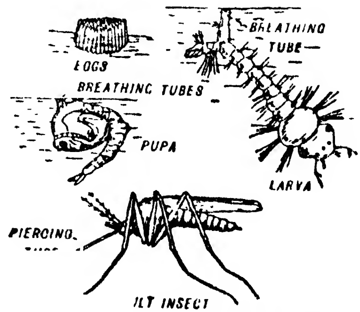


Fig. 119. Life history of a Gnat.

Insects as disease carriers

Many human diseases are due to germs. Sometimes germs reach our bodies in our food or water, or are blown about in the air, or are carried to us by insects. Many small animals similar to the Amoeba which cause diseases, for instance malaria fever, are also carried from man to man by insects.

The house fly settles on filth, and dirt containing germs sticks to the hairs on its body and legs. These germs may later get on our food. Flies carry the germs of tuberculosis from the spittle on which they alight. It is very important to keep down the number of flies. This can be done by covering up, burning

or disinfecting rubbish and dung, so that flies have no breeding places. Killing adult flies by means of fly papers helps very little.

Mosquitoes carry the germs of malaria fever. When a mosquito stings a malaria patient, the insect sucks up germs with the blood as it is feeding. Then, when the mosquito stings another man, there will be malaria germs in the liquid squirted into the wound. The number of mosquitoes can be lessened by pouring oil on the surface of water containing their larvae. Then the larvae cannot push their breathing tubes to the surface to take in fresh air, so they die. English gnats seldom carry diseases, but the liquid put into the wound when they sting often causes inflammation and painful swelling.

Fleas (Fig. 120) pass through larval and pupal stages, the larvae living in cracks in the floor. Different animals have different kinds of fleas. Monkeys, however, have none; what they are always searching for is flakes of dead skin. Rat fleas carry the germs of plague, and were the cause of the Black Death of the fourteenth century. The flea may suck the blood of a rat which has plague, and then attack a man, so passing the germs on to him. The number of fleas can be reduced by keeping houses clean, but it is really of more importance to keep down the number of rats.

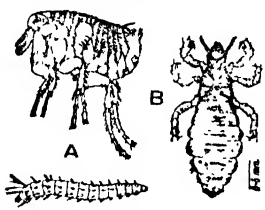


Fig. 120. *A*. Flea The upper figure shows the Flea, the lower figure its larva. *B*. Louse.

The ***Louse*** (Fig. 120) spreads typhus fever. As it sucks blood, at the same time it deposits waste matter (faeces) containing fever germs on the skin of its victim. The person bitten scratches the irritating spot, and rubs in the germs. The louse attaches its eggs to human hairs. They are commonly called "nits".

Insect pests

The number of insect pests attacking and eating farm and garden crops is very large. Black Aphids or "Blight" on beans

are well known. The larvae of some butterflies, moths, flies and beetles do much damage to plants, especially those that we cultivate to eat. They may eat roots, as for instance the Carrot fly and Cabbage-root fly larvae, or they may eat the leaves, as the Colorado beetle which eats potato leaves. The plants then grow very little or may even die.

Beneficial insects

Sometimes the damage done by insects to plants is so serious that steps have to be taken to kill the pests. This is usually done by spraying the plants or the soil with chemicals. All insects, however, are not pests. Some insects benefit us by eating or killing certain pests, for instance Lady-birds eat "Blight". The most useful insect is the Ichneumon fly, which lays its eggs in or on the larvae of insect pests. The Ichneumon fly larvae live as parasites inside the bodies of their prey, on which they feed, thus gradually killing them (Fig. 121).

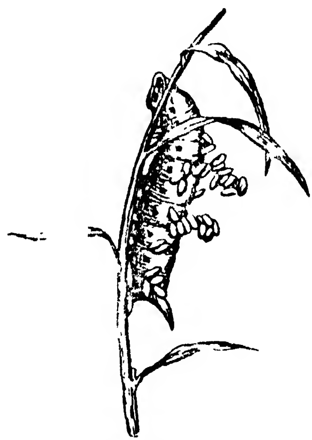


Fig. 1 Caterpillar showing larvae of a parasitic insect just emerging from it.

Parasites help to keep the numbers of the harmful pests within reasonable limits. Now, insect pests are often accidentally taken on ships from one country to another. In the new country none of their enemies may be present, so they rapidly increase in numbers. For instance, the larva of a certain moth was ruining the coconut industry of Fiji in the South Seas by eating the leaves of the palm trees. But lately a certain fly, whose larvae live as parasites in the moth larvae and destroy them, has been introduced into the island. In this way the numbers of the moth have been greatly reduced in a short time.

Rabbits introduced into Australia have become a plague, for there are no stoats, weasels or ferrets to kill them off. This is another example of what happens when the balance of nature is upset.

Social insects

Bees, wasps and ants are called social insects because they live together in communities. The young ones do not leave their parents, but work together to bring up further generations.

The Bee

Bees usually make their nests in hollow trees, but ***hives*** made by man are more convenient places for them. Nearly all the bees in a hive are ***workers*** (Fig. 122*d*). These are really females that will never lay eggs. Only one female in the hive can lay eggs; she is called the ***queen***. There are also male bees, called ***drones***. The workers do all the work except that of laying the eggs.

When bees hatch out of the egg they start life as white legless larvae (Fig. 122*d*), which turn into pupae. The pupae have the beginnings of legs, wings and eyes. The pupae turn into queens, workers or drones. A queen may live five years, but in summer workers die after eight weeks. Three weeks elapse before the coming out of the pupal stage.

Inside the hive is a ***comb***, which consists of six-sided cells of wax, with passages between them, made by the workers. The queen lays an egg in some of these cells. Other cells are stores for food, either honey or pollen.

Men have different jobs, but a worker bee does all the various jobs in the hive one after the other as she grows older. First she cleans out the cells from which new insects have emerged, so that the queen can lay another egg there. Then she feeds the helpless larvae with honey and pollen from the stores. After this she sucks nectar from the mouths of older workers; inside her body the nectar is changed into honey, which she squirts into the store cells. She also packs pollen into pollen cells, and carries any dirt

out of the hive. Then she begins to build new cells with wax which is formed (secreted) in her abdomen. During this period of her life she flies also out of the hive occasionally, each time going farther afield, until she knows the landmarks in the neighbourhood. When five weeks old she is a doorkeeper, smelling bees with her feelers and driving off strangers. Finally she goes out and

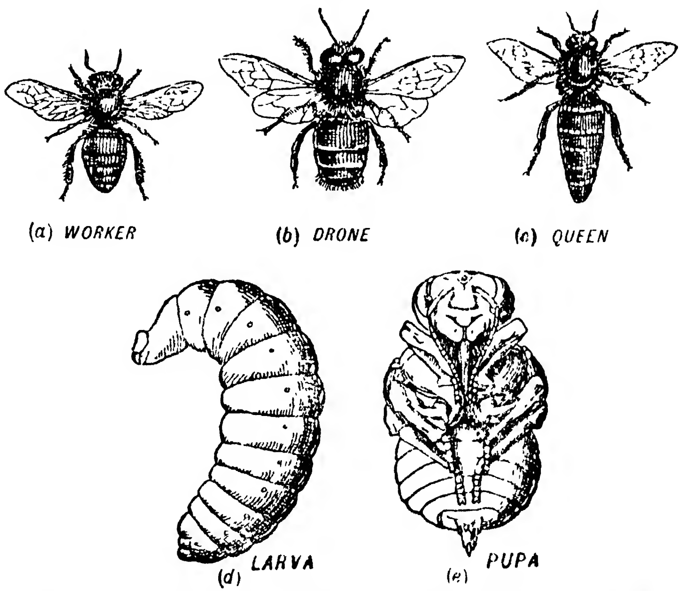


Fig. 122. Larva and pupa of Bee. Different types of hive bees.

gathers nectar and pollen from the flowers. For carriage the pollen is packed into sticky balls on the hairs of her hind limbs.

When the hive is getting overcrowded, a few larvae are specially raised by the workers to become new queens. Extra large cells are made, in which eggs destined to become females are laid. The larvae are given food with more pollen than usual in it. This turns female larvae into queens, instead of into workers. Just before the new queens emerge from their pupae, the old queen flies out of the hive with half its workers. This is called a ***swarm***.

If a bee keeper is quick enough he gets the swarm to enter an empty hive.

Then a new queen emerges in the old hive, and the colony starts off afresh with its new queen. She begins her career by flying out on a wedding flight followed by the drones. On the return of the newly wedded queen, the workers kill the other queen pupae. In the autumn the drones are all turned out of the hive and either die of starvation or are stung to death by the workers.

Ants

As in the case of bees, there are male, female, and worker ants (Fig. 123). The social life of ants, however, is more complicated even than that of bees. The worker ants do one job only. Some kinds of ants bring pieces of leaves into their nests and manure them with their own waste matter, or ***faeces***, so that fungi grow on the leaves. The ants enjoy eating these fungi. They also keep "cows". Certain plant lice (aphids) produce a sugary liquid which ants like, and the ants tickle them to get it. Other ants capture the workers of different kinds of ants and make their captives work for them as slaves.

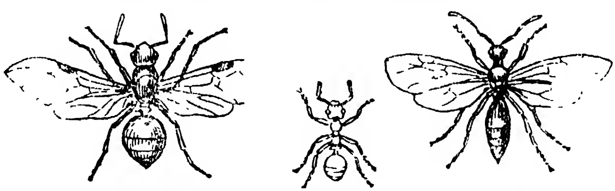


Fig. 123 Wood Ants.

Questions

1. Make a list of the living and non-living things around you.
2. How can you tell living from non-living things?
3. Is it true to say that animals move from place to place, and plants do not? Give reasons for your answer.

4. "Plants make the whole world's food supply." Is this statement true? Why?

5. Give three examples of movement in plants. What are the uses of these movements to the plant?

6. Do you think the Amoeba is a wonderful animal? Why?

7. On what does a Hydra feed? How does it catch its food?

8. Describe the ways by which a Hydra can reproduce itself.

9. How is a Coral formed?

10. Of what use are Earthworms in the garden?

11. Describe how Spiders catch their food.

12. Write a short essay on Snails and animals similar to Snails. Say which are useful to man and which harmful, and why.

13. Which is the better method, insect pollination or wind pollination? Why?

14. Is it of any advantage to plants to have their pistils and stamens in different flowers? Give your reasons, with examples.

15. What are the chief features of (*a*) wind, (*b*) insect pollinated flowers? Give an example of each.

16. Why must seeds be scattered? Briefly describe, giving examples, the four ways by which seeds are dispersed in nature.

17. What is meant by germination? What conditions must be fulfilled before seeds will germinate?

18. How would you recognise an insect? Make lists of the insects you know (*a*) with two pairs of wings, (*b*) with one pair of wings, (*c*) with no wings.

19. How do the Amoeba, Earthworm and Butterfly breathe?

20. How can you tell a female from a male Gnat? Which is dangerous? Why?

21. Give two examples of insects which spread disease. What is the special danger of the House fly?

22. Name six insects useful to man and six that are harmful. Give reasons for putting them into each group.

23. What insects that you know make noises? Describe how these noises are made.

24. What do we mean by "Social Insects"? Describe the life in a bee hive.

Experiments

N.B. Careful drawings should be made of all specimens examined. Carefully labelled diagrams are often more useful than notes.

1. Examine the sleep movements of flowers such as the Daisy, Californian poppy and Tulip.

2. Put a Clover plant into darkness. After an hour or so the leaves will have folded down.

3. Lightly stroke the lower side of a tendril of Bryony with a match. It gradually bends at the point touched.

4. Test any animals that you have in your school to find whether they can see, hear, smell, taste or feel.

5. Strip off the skin of a leaf, for example, an Iris leaf, and look at it under the microscope to see the cells.

6. Scrape the inside of your cheek, and examine the cells so obtained under the microscope.

7. Study living Amoeba under a microscope.

8. Examine living Hydra with a lens. Note retraction when it is touched and expansion again after a time. Look for buds.

9. Cut off the tentacles of Hydra. In a few days new ones will have grown.

10. For demonstration living sperm cells can be taken from the genital duct of a Water Snail and examined under a microscope in the blood of the Snail.

11. Examine with a lens an Earthworm which has been killed by putting it into boiling water.

12. Study the movements of an Earthworm as it moves forwards. Touch the front end of the Earthworm and see what happens.

13. Dip a glass rod in xylol and put it near the worm. It will move away. Put the rod near different parts, and find which part of the worm is most sensitive to smell.

14. Put some worms in a jar of moist soil, with leaves placed on top. Look for the leaves in a day or two.

15. Examine the external features of a Crayfish or Lobster.

16. Keep a Spider in a jar containing twigs. Examine it carefully. Watch it spin a web. Feed the Spider with living flies and watch what the Spider does.

17. Find as many different kinds of webs as you can. Cut the "telegraph wire" of one web. Then put a live fly in the web. Does the Spider come to the web?

18. Put a Water Snail in a jam jar. Notice the waves passing forward over the surface of the foot as it crawls on the glass; also its mouth opening and closing showing its tongue. Look for eyes and breathing pore.

19. Take a Land Snail and show that it can smell by putting a glass rod dipped in xylol near the tentacles, when they are withdrawn. Move a pencil towards its eyes to find out how well a Snail can see.

20. Examine a Buttercup flower and cut it through longitudinally. Use a lens.

21. Make a collection of wild flowers and name them. Wild flowers can be pressed, labelled and grouped according to

(*a*) Families.
(*b*) Habitats, i.e. where they grow.
(*c*) The kind of soil in which they grow.

22. Look at pollen grains under the microscope. Shake pollen grains into 10 per cent. sugar solution and examine after a time to see the pollen tubes.

23. Study the structure of the Dead-nettle. Press down the "landing stage" and see what happens.

24. Make a collection of flowers similar to the Dandelion. Have they all two kinds of flowers? Look for flowers with ripe anthers and ripe stigmas.

25. Look at pin-eyed and thrum-eyed Primroses.

26. Examine the two types of Willow catkins. What is the difference between them?

27. Examine a grass flower.

28. Examine the two kinds of Hazel flowers.

29. Make a collection of fruits. Group the fruits according to their method of dispersal. (Juicy fruits can be kept in a 2 per cent. solution of formaldehyde.)

30. Grow as many different kinds of seeds as you can. Note carefully the different stages in germination.

31. Find out under what conditions seeds grow best. Prepare a number of jars using pea seeds only (see text, page 97). Put the seeds to grow under the following conditions:

Jar 1. With light, air, water and low temperature.
Jar 2. With light, air, water and high temperature.
Jar 3. With light, air, water and moderate temperature.
Jar 4. With light, air, no water and moderate temperature.
Jar 5. With light, water, no air and moderate temperature.
Jar 6. With air, water, no light and moderate temperature.
Jar 7. With light, air, water and moderate temperature using seeds killed by boiling them.

32. Grow a bean plant in a pot. When the stem is about 5 inches long, put the pot sideways. Notice the curvatures.

33. Grow some beans for a short time, then put them upside down and notice the curvatures.

34. Put a potted plant in a box with the light entering at one end only (Fig. 115). Note the result after a few days.

35. Set up the apparatus shown in Fig. 114. Note results.

36. Set bean seeds at different depths in pots. Note when the shoots of each appear.

37. Get a clear plot of ground but set no seeds. Note what plants grow. Where have the seeds come from?

38. Examine, with a lens, a Cockroach or any other large insect.

39. Collect as many different kinds of insects as possible. Keep them alive and study their habits.

40. Examine a Grasshopper. Look with a lens for the sound-producing organs and the ear drums.

41. Find and keep alive any stage of Butterfly or Moth and note their behaviour, date of hatching of eggs, moults and pupation.

42. Watch Butterflies feeding on a drop of sugar solution.

43. Examine living larvae of House fly or Blow fly. Notice how they crawl away from the light. Examine the pupae and adult flies.

44. Examine male and female Gnats.

45. Catch Gnat larvae and pupae and study their behaviour and structure. Cover the surface of the water with oil and see what happens.

46. Make a collection of insects which are harmful to plants.

47. Watch Bees collecting nectar and pollen and pollinating flowers.

48. Make a note of all insects that you see pollinating flowers.

SECTION IV. MEASUREMENT

Chapter 11

GRAVITY

Is it possible to fall off the earth?

Knowing that the earth revolves from west to east on its own axis once every day, has it ever occurred to you to ask why, when a balloon goes straight up in the air, the earth does not slip along beneath it and leave the balloon behind? Obviously there is a force acting on the balloon which exerts some influence on it even when it has left the earth. For very many years people would not believe that the world was round. They argued that, if it were, people who visited the underside, i.e. the southern hemisphere, would drop off.

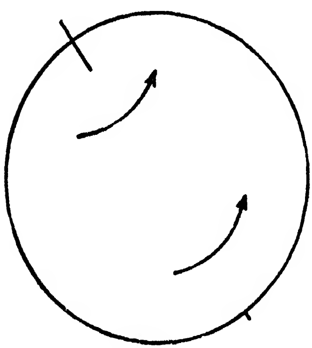


Fig. 124.

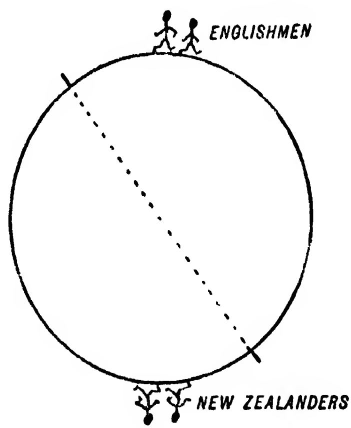


Fig. 125.

Now we know beyond doubt that the earth is round and that New Zealanders, living in the southern hemisphere on the opposite side of the earth to ourselves, are held on to it by the same force which prevents *us* from making a sudden departure from the earth.

How the earth and all other heavenly bodies are held in space

All the planets (other worlds like our earth) are continually revolving around the sun in paths known as their ***orbits***, and out of which they never move.

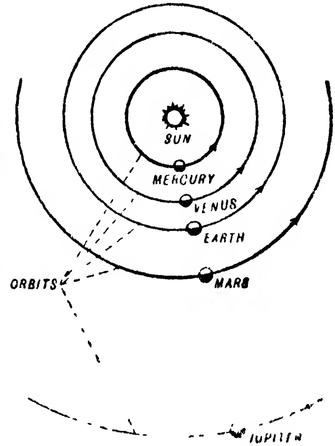


Fig. 126. Some heavenly bodies and their orbits. This figure is very much out of proportion.

Every object, either in the world or the universe, attracts every other object to it. ***The larger and more heavy the objects and the shorter the distance between them the greater is the force attracting the objects to each other.*** This force is known as ***gravitational attraction.***

Now the sun and the earth are attracting each other together and, as the lighter body is the one that does most of the moving when attracted, the earth should move towards the sun. There are, however, many heavenly bodies on the side of the earth opposite from that on which the sun lies. All of these attract each other, and the earth, and the sun. All these forces acting together, the one upon the other, have balanced themselves so that the planets are held in their particular orbits.

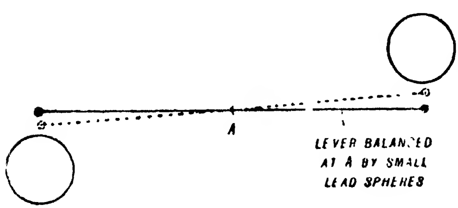


Fig. 127.

A certain professor, named Cavendish, discovered many things about this force called gravitational attraction. He set up apparatus similar to that shown in Fig. 127, and when he placed the two large solid lead spheres in position discovered that the small spheres were pulled out of position

into that shown by the dotted line. The movement of the small spheres in Fig. 127 has been exaggerated. In fact, small telescopes were used to observe it.

Is the earth hollow?

In 1740 a French scientist named Bouguer found the gravitational pull of a very large mountain in South America, called Mount Chimborazo, on the bob or lump of lead at the end of a plumb line. Like this scientist you know that the earth pulls all substances down to it unless they are supported by some other force. It is this attraction that causes plumb lines to hang vertically, i.e. perfectly upright. Now Bouguer hung up a plumb line on the side of Mount Chimborazo, and found that the force of attraction between the huge mountain and the small lead bob pulled the plumb line out of its true position, as shown by the dotted line in Fig. 128.

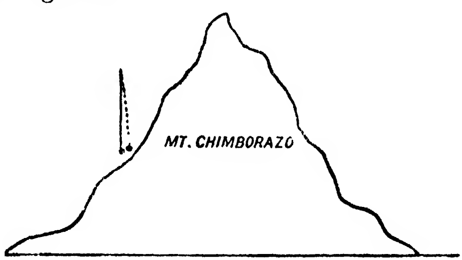


Fig. 128.

From the size and form of the mountain Bouguer found that, if its density were the same as the earth, the mountain should have pulled the bob thirteen times more strongly than it did. In other words, Bouguer found that the earth was thirteen times as dense as the mountain.

Although his calculations were not accurate owing to weather conditions, etc., they were sufficient to show that the earth was not hollow.

Actually, the earth is about five and a half times as dense as water, and weighs 6,000,000,000,000,000,000,000 tons.

Weight

The force with which the earth is constantly pulling all things towards its centre is known as the ***force of gravity***, and is actually the ***weight*** of these things. By knowing the weight of any object, then, we know the force with which the earth attracts the object to itself. A ten-stone man is held to the earth by a force of 140 lb.: the force of gravity on half a pound of butter is half a pound.

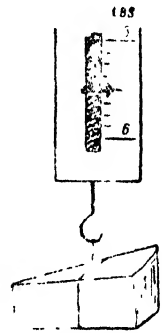


Fig. 129.

This force of gravity on any object can be measured by a spring balance. When the object is hung on to the hook of the spring balance the force of gravity pulling the object downwards causes the spring to stretch. An indicator attached to the spring shows the force with which the earth is pulling the object and so we get its weight

The indicator shows that the earth is pulling the piece of cheese (Fig. 129) with a force of $5\frac{1}{2}$ lb. Therefore the weight of the cheese is $5\frac{1}{2}$ lb.

Weight reducing without slimming, and vice versa

You have read that the gravitational force which attracts two bodies towards each other is greater the nearer they are together and the heavier they are.

Aeroplane pilots flying at high altitudes being further away from the centre of the earth weigh less than when they are down on the ground. In spite of this fact that they weigh less the pilots still have the same quantity of flesh and bone, and have not been reduced in size.

A coal-miner at work weighs more than when he is at home. This is because when he is down the pit he is nearer to the earth's centre.

The moon

The moon is much smaller than our earth and is made of lighter material. Owing to this it holds things to its surface much more weakly than does the earth.

As Fig. 130 illustrates, a boy who can jump 4 feet on the earth would be able to jump 24 feet on the moon.

As two-storeyed cottages are only about 20 feet high such a boy on the moon would be able to jump over a cottage comfortably.

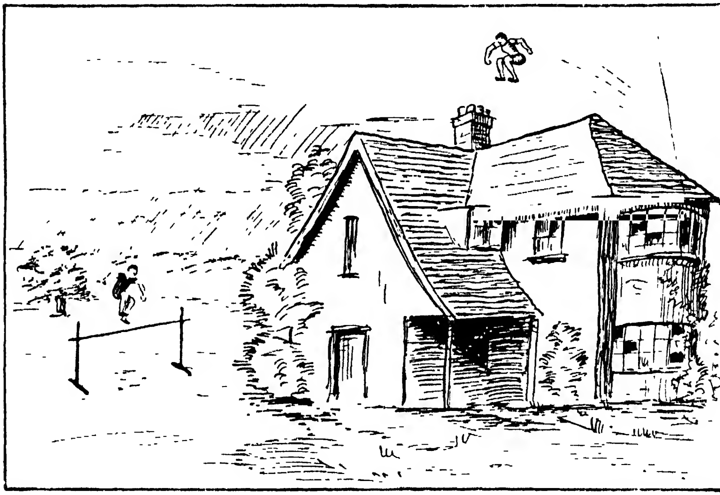


Fig. 130.

If 6 lb. of butter were bought in a shop here and weighed by a spring balance on the moon the butter would only weigh 1 lb., although there would be the same amount of butter there. A six-stone boy without losing any flesh would weigh only one stone on the moon.

From this you will agree that weighing by means of a spring balance does not always seem to be fair.

Trickery with the spring balance

The earth is not quite a sphere, i.e. it is not a perfectly round ball, its diameter from pole to pole being less than its equatorial diameter. Fig 131 gives an exaggerated example of this. It is clear, therefore, that if we go from the Equator to the

North Pole we shall be getting nearer to the centre of the earth. Consequently we shall weigh more. At the North Pole the pull of the earth is more than that at the Equator by about 1 in 200. That is, a man weighing 14 stones 3 lb. or 199 lb. at the Equator would weigh 14 stones 4 lb. or 200 lb. at the North Pole.

The equatorial diameter of the earth is 7926 miles.

The diameter from pole to pole is 7899 miles.

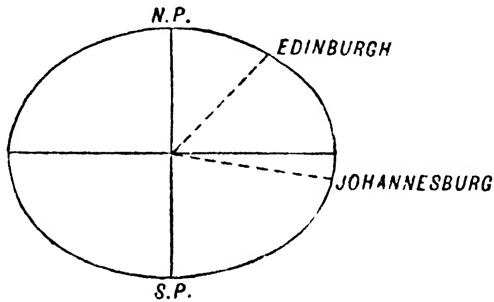


Fig. 131.

Towards the end of the nineteenth century some clever rogues who knew of this increase in weight as the North Pole is approached bought some diamonds by weight in Johannesburg. Johannesburg, a town in South Africa near to the Equator, is the centre of the diamond mining industry. These rogues then took their diamonds to Edinburgh where they sold them by weight. Now as the diamonds had been weighed by spring balance in both cases, they weighed more at Edinburgh than they did at Johannesburg. Consequently these rascally diamond merchants cleared off with a profit that was very much larger than it ought to have been.

Weighing by scales

If things were always weighed on scales such as those shown in Fig. 132, we should not notice any change in weight whether we were at the Equator, North Pole, or on the moon. This is

because any increase or decrease of either the earth's or moon's pull on the 1 lb. weight would be just the same for the 1 lb. of cheese, and so they would always remain balanced.

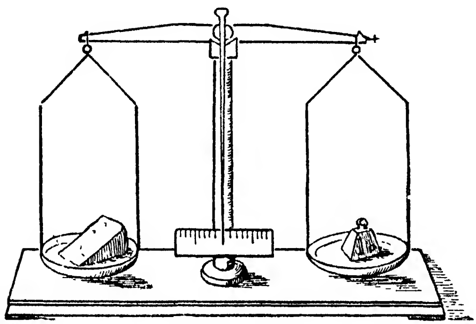


Fig. 132.

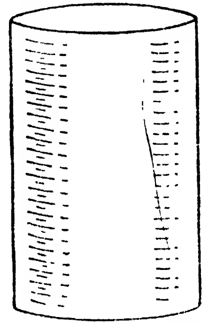


Fig. 133. The actual size of the Imperial Standard Pound.

Mass and the Imperial Standard Pound

Scientists get out of this difficulty in connection with weight by referring only to the ***mass*** of an object.

They speak of an object which weighs 5 lb. as being a 5 lb. mass, and although the weight of this object may vary according to its position in the universe its mass is always the same, viz. 5 lb.

What the scientists really mean is, that the object of 5 lb. mass will weigh five times as much as another particular object, a certain lump of platinum kept at the Board of Trade in London, if both these objects are weighed in the same place.

This lump of platinum is about the size of a pile of halfpennies one and a half inches high. It is known as the Imperial Standard Pound. Scientists call it the Unit of Mass.

Discovering underground lakes

As water and oil, particularly the latter, are much lighter than earth their gravitational attraction for objects is consequently less.

Nowadays, if the presence of an underground lake is suspected the people who are searching for it use an instrument that will measure the earth's pull with amazing accuracy. It is an extremely delicate type of spring balance. When this instrument is held over, what is afterwards proved to be, an underground lake it shows that the earth's pull is slightly less than normal.

Tides

When you have been staying at the seaside you will have noticed that at one time during the day the sea is well up the beach, whilst at another it seems to have run right away from the beach. The rise and fall of the sea are known as ***tides***, and to many people they are very puzzling.

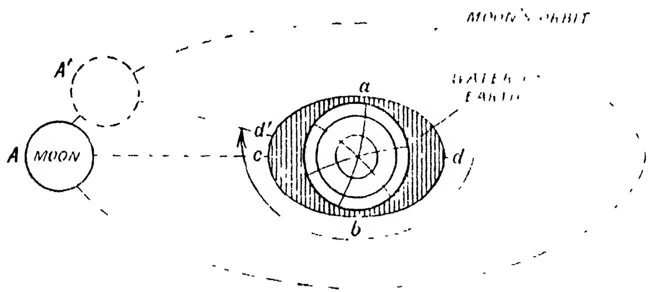


Fig. 134. The formation of tides by the pull of the moon.

We have already seen that every body attracts every other body with a force depending upon the sizes of the bodies and their distance apart. The moon attracts the waters of the earth, and, as they are soft and pliable the moon can pull them slightly towards it. From Fig. 134 it is seen that when the moon is at *A* high tides will be produced at *c*. High tides are also produced at *d* as, at this point, the waters are least attracted by the moon. At the same time low tides will be experienced at *a* and *b*. Now as the earth rotates on its axis once in 24 hours we shall find that at the end of 12 hours *d* will be in the position formerly occupied

by *c*. During this time, however, the moon will have moved from position *A* to *A'*. This is due to the fact that the moon travels round its own orbit once in 28 days. Therefore, in order for *d* to be in a direct line with *A'* it will have to move to the position *d'* and at *d'* a second high tide will take place. As the journey from *c* to *d'* takes about 25 minutes it will be seen that, at any one spot, high tides will be experienced every 12 hours 25 minutes.

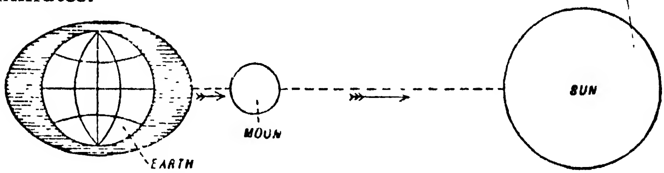


Fig. 135. Showing the formation of spring tides.

When the moon is full both the moon and sun attract the waters of the earth in the same direction (see Fig. 135). Consequently the high tide is very much higher than is usual. These tides are known as ***spring tides***.

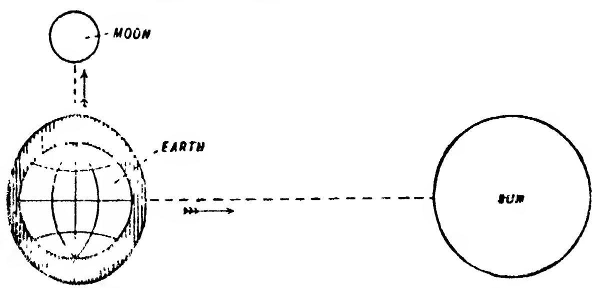


Fig. 136. Showing how neap tides are formed.

At other times the moon will be pulling one way and the sun the other (see Fig. 136). Consequently the high tides caused by the moon will not be so high as usual, and the low tides not so low as usual. These tides are known as ***neap tides***. Each kind of these special tides occurs once a fortnight.

Chapter 12

TIME, SPACE AND SOME INSTRUMENTS FOR MEASURING VOLUME

(a) *Time. The hour glass*

It is probable that you have often seen the picture of an old man with a flowing beard and girdled robe who carries over his shoulder a scythe and in one of his hands an instrument like that shown in Fig. 137. This old man is known as Father Time.

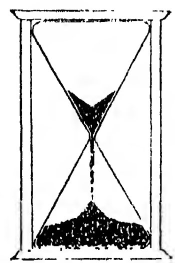


Fig. 137. An hour glass.

The hour glass was a piece of apparatus used in days gone by for telling time. It is so arranged that it takes one hour for the sand in the top half of the glass to trickle through to the bottom half. At the end of the hour the glass had to be inverted or turned upside down again, so that the next hour could be counted. These hour glasses were not very good for measuring time because people often forgot to invert them when the sand had all trickled through to the bottom half.

Small ones are still used to-day and are called "egg boilers". They are made so that an egg put to boil will be properly cooked by the time that ***all*** the sand has trickled through from the top to the bottom half of the glass.

The day

The day is usually measured by the length of time from when the sun is in its highest position in the heavens until it is again in this position, i.e. from one noon until the next noon. This is known as the ***solar day***, and can be measured by the sundial. A sundial is arranged so that the side marked *AB* (Fig. 138) is

always facing due south. If you turn to the end of the chapter you will find out how to make one.

The astronomers measure the exact time it takes for the earth to go round once on its own axis. This they call the ***sidereal day***. The sidereal day is a little shorter than the solar day. It is measured by observing the time taken from when a particular star appears in a certain position in the sky until the next time it appears in exactly the same position.

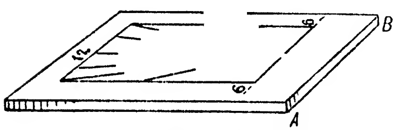


Fig. 138. A sundial.

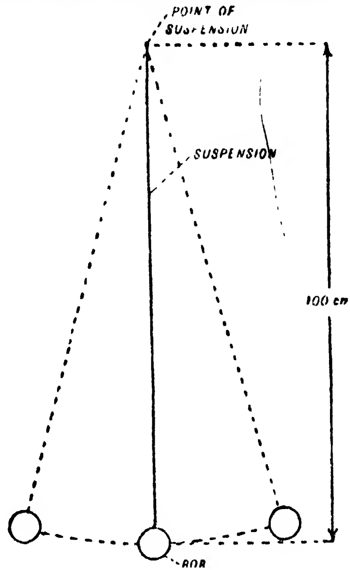


Fig. 139. A pendulum that makes one swing every second.

The second

As you know, the day is divided up into twenty-four hours and each hour is split up into sixty minutes, whilst each minute is made up of sixty seconds.

A fairly accurate measure of a second can be obtained by erecting a pendulum or light plumb line as shown in Fig. 139.

A pin can act as the point of suspension or point from where the pendulum hangs; the suspension can be of cotton or thread; and the bob can be a small weight. Now if the length of the pendulum from the point of suspension to the centre of the bob is 100 cm., then it will take one second to swing from one side to the other.

When doing this experiment you must be careful not to give the pendulum too big a swing. Otherwise you will not get such a good result.

(b) Space. Old-fashioned measures

Spaces are measured by length or distance. Very often when considering distances we do so lazily. We describe short distances as being "a stone's throw away", and distances of roughly a mile we speak of as being "twenty minutes' walk".

In bygone days very few measurements were definite. People used to measure by cubits and spans. A cubit is supposed to be the distance from the elbow to the tip of the middle finger; and the span, the distance that the hand could stretch. As the spans and cubits of differently sized people varied tremendously, there was often a great deal of dissatisfaction, which gave rise to many quarrels and troublous scenes. To avoid this trouble a standard of measurement was introduced. This standard is the distance between the marks on two pieces of gold let into a bronze bar which is kept at a certain temperature. It is known as the ***Imperial Standard Yard***.

As metal can age and the standard may be lost or destroyed by fire as the first one was, scientists often take as their standard a number of wave-lengths of rays of certain coloured light.

Our longest distance is a ***mile***, but astronomers find this much too small to measure how far away some of the stars are. They use a unit called a ***light year***.

Light travels almost instantaneously, i.e. very, very rapidly, for its speed is 186,400 miles per second. A light year is the number of seconds in one year multiplied by 186,400 miles. You can see that it is an enormous number. In fact

$$1 \text{ light year} = 6{,}000{,}000{,}000{,}000 \text{ miles},$$

and the nearest star is a distance away of 4·3 light years.

Sirius, the brilliant Dog Star, is 8·6 light years away.

(c) Some instruments for measuring volume

It is fairly easy to find the amount of space that regular solids, such as cubes, occupy; but how is one to find the volumes of irregular solids like a pebble or a lump of coal? Often it is necessary to find the volumes of spongy things like coke, and also of small quantities of liquids.

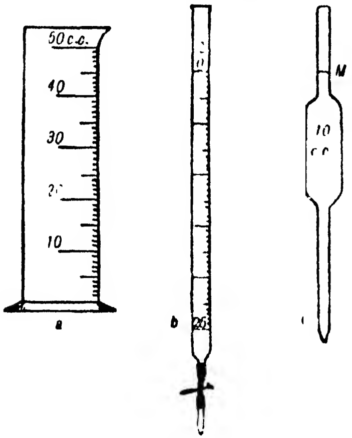


Fig. 140. Instruments for measuring the volumes of liquids. *a.* A measuring jar or graduated cylinder. *b.* A burette. *c.* A pipette.

Fig. 140 shows a number of glass instruments that will help us in finding the space that these irregular bodies occupy.

If the object whose volume is to be measured is solid and will not dissolve in water, it can be immersed or "sunk" in some water in a measuring jar. If the heights of the water before and after the object is immersed are taken, then, by subtraction, we can obtain the volume of the object.

In science the volumes of liquids are nearly always measured in cubic centimetres, c.c. for short. Fig. 141 shows you an actual size drawing of a cube whose volume is 1 c.c.

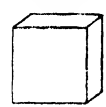


Fig. 141. An actual size drawing of a cubic centimetre.

When taking the reading of the volumes of liquids in the apparatus shown in Fig. 140 you will notice that the surface of the liquid is curved. You must take care to read at the bottom of this curve, which is known as the ***meniscus***, by getting your eye directly on a level with it as shown in Fig. 142. The diagram in this figure also shows you that unless you ***do*** get your eye on a level with the bottom of the meniscus the reading will be wrong.

The burette is a glass tube graduated (that is to say "stepped off", or "marked off") in cubic centimetres, which is used for

measuring small quantities of liquids. You will notice that the burette seems to be marked backwards as the top mark is 0 c.c. This is because the liquid that is being measured out by it is poured in at the top and run off at the bottom by opening the tap or stopcock.

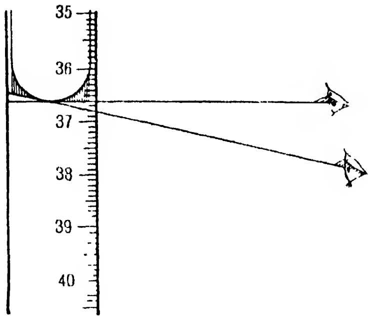


Fig. 142. This figure shows that you must keep your eye on a level with the bottom of the meniscus if you are to obtain a correct reading.

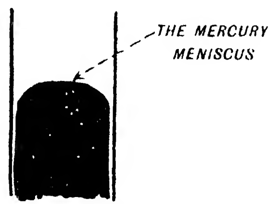


Fig. 143. A mercury meniscus.

The ***pipette*** is a glass tube used for obtaining definite quantities of liquid at once, such as 10, 25 and 50 c.c., and so on. When using it the narrow end is placed in the liquid. This is drawn into the pipette above the mark *M* by placing the lips at the top end and withdrawing the air inside. The thumb is then placed firmly over the upper end of the tube. By slightly releasing the pressure of the thumb you can run out the liquid, a spot at a time, until the bottom of the meniscus is resting, as it were, on the mark *M*. You have then the exact amount of liquid in the pipette that is marked on the wide portion of the tube.

Summary

Gravitational attraction is the force with which all objects attract each other.

This force increases with

(*a*) the amount of material in the objects, and
(*b*) the nearer they are together.

The gravitational attraction of the earth is known as the ***force of gravity***. It is this force that prevents us from falling off the earth. The gravitational attraction of the moon is one sixth of that of the earth.

All the heavenly bodies are held in space by their gravitational attraction for each other.

The ***weight*** of an object is the force with which the earth pulls it. The weight of an object varies with its distance from the centre of the earth. Thus an airman whilst flying weighs less than he does on the ground, and a miner weighs more at work than when he is at home.

The ***mass*** of an object tells you the amount of material that is in the object. It has nothing to do with size or volume.

Weight is measured by spring balances.

Mass is measured by scales.

Tides are caused by the moon's pull on the waters of the earth. As the moon revolves around the earth once in 25 hours we have tides every 12½ hours.

Spring tides are caused about once a fortnight when the pull of the moon and that of the sun upon the earth are in the same direction. They are very high and very low.

Neap tides are also caused once a fortnight. They occur when the moon's pull and the sun's pull on the earth are in opposite directions. These are neither so high nor so low as the spring tides.

A ***pendulum*** which is ***100 cm. long*** from the point of suspension to the centre of its weight or bob ***will swing once every second***.

1 light year = 6,000,000,000,000 miles.

The curved surface of a liquid is known as the ***meniscus***. For mercury it curves downwards (see Fig. 143), for all other liquids it curves in the opposite way.

Questions

1. Describe (*a*) Why we are not able to fall off the earth.
(*b*) How the heavenly bodies are held in space.

2. If a man could live for a part of his life on the earth and a part of it on the sun, what are the main differences he would experience? Say what they are due to.

3. What is the difference between ***mass*** and ***weight***? Describe how each of these is measured.

4. Why is it that the use of the spring balance for weighing is sometimes unfair? Mention any other peculiar or strange things you know of in connection with weight.

5. How are tides formed? What are spring tides and neap tides?

6. Why is Father Time always shown carrying a scythe? Describe the various ways, apart from clocks and watches, that we have of measuring time.

7. What is a meniscus? Draw a diagram showing the care that must be taken in reading the levels of liquids in measuring instruments.

8. Fig. 144 shows a portion of a burette marked off in c.c. and tenths of a c.c. The lines *A*, *B*, *C*, *D* represent four meniscuses. Write down in c.c. the volume of the liquid that would be between:

A and *B*, *A* and *C*, *A* and *D*
B and *C*, *B* and *D*, *C* and *D*.

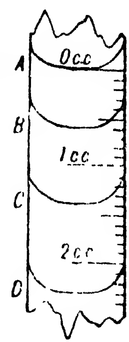


Fig. 144.

9. Make a drawing of the metric weights that appear in the box of weights used with your balance. At the side write what decimal parts of a gram the milligram weights are.

Practical work

1. ***How to make a spring or an elastic balance.*** If your balance is to measure in ounces your spring must be a light one. Your teacher will be able to provide you with one or tell you where you may get the right kind. A good substitute for the spring is a stout piece of india-rubber elastic. The elastic-rubber balance, however, must be checked every few weeks.

To mark off your scale put weights from $\frac{1}{4}$ oz. upwards into the pan and mark on the cardboard the position of the indicator against it. Also mark it off in metric weights.

Use the completed balance to weigh any articles you have in your pockets.

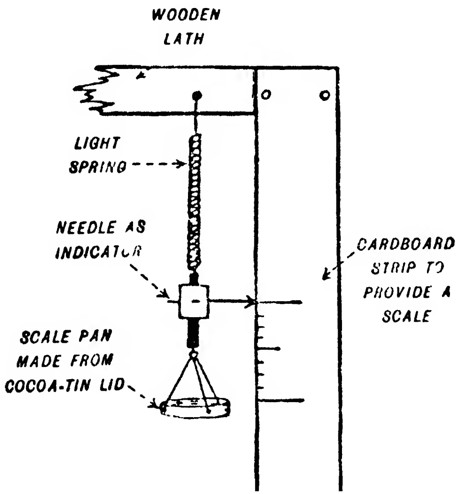


Fig. 145.

2. ***How to use the lever balance and to check your spring balance.*** Look at Fig. 146 and learn the names of the various parts of the lever balance. Now examine the box of weights. Weigh the articles that you weighed on your spring balance and see if you obtain a result within 5 gm.

You must carry this out by putting the article to be weighed on the left-hand pan, and the weights on the right-hand pan. Why should you do this? Start with the largest weight and work downwards until you obtain a balance. ***The beam must always be lowered before you take off or add any of the weights.***

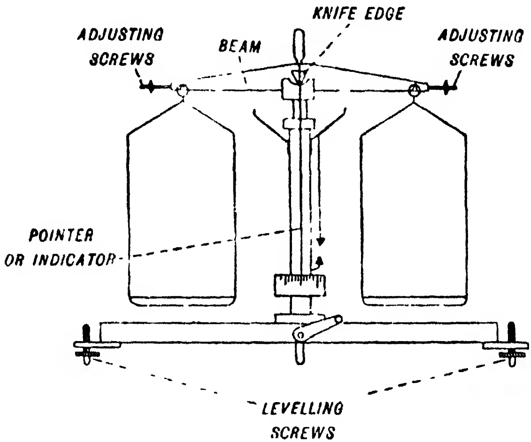


Fig. 146.

3. How to make an hour glass. Obtain a cork that will fit two bottles of the same size that you have in your possession. Burn a hole through the centre of the cork with a red-hot knitting needle, and hollow out the ends as shown in Fig. 147 *b*. Pour sifted sand into one bottle and set up the apparatus as shown in Fig. 147 *a*.

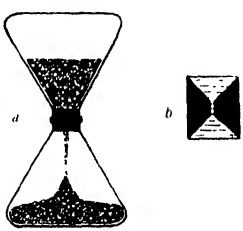


Fig. 147.

4. A "seconds" pendulum. Take a piece of lath about 44 inches long and plane it smooth. Now moisten the inside of a small shallow tin lid with "spirits of salts" and fill it with

solder. This is to act as the "bob" and should be attached or fixed to the lath as shown in Fig. 148. The "bob" can be screwed into the lath by sinking a screw into the middle of the solder. Now, from the centre of the "bob" measure 100 cm. up the lath and drill a $\frac{1}{10}$ inch hole. If the pendulum is supported by a fine nail through this small hole it will swing once every second.

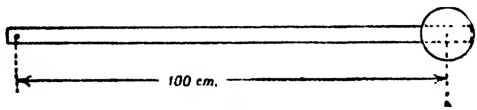


Fig. 148.

5. *A model sundial.* To withstand all weather conditions the sundial should be made of wood which should be painted or stained with creosote. The gnomon must be fixed on to the dial

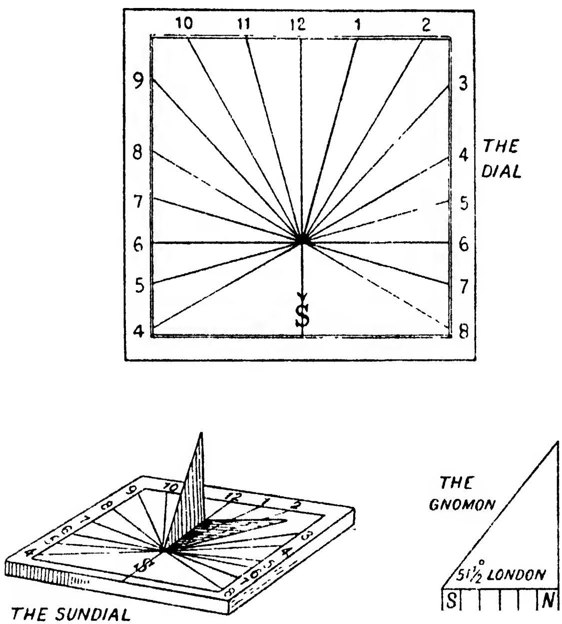
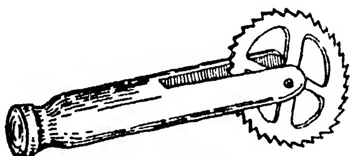


Fig. 149.

in a N.S. position with the angle pointing South. The hours can be marked by putting it out in the sun. If desired the angles shown in Fig. 149 can be copied.

6. *How to make an opisometer.* An opisometer is an instrument for measuring the lengths of curved lines quickly. Make one from a clock wheel and a clothes peg as shown. The hole for the spindle can be made with a red-hot needle. Make a scratch on one of the teeth to act as a starting point. Now wheel your instrument along a curved line and note the number of turns and fraction of a turn taken. Now run it for the same amount along a ruler. In this way you will obtain the length of the curved line.



AN OPISOMETER
Fig. 150.

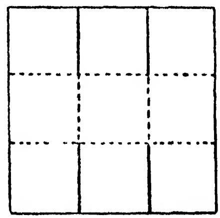


Fig. 151.

7. *How to make a hollow cubic centimetre and a hollow cubic inch.* Cut out a three centimetre square (see Fig. 151). Fold along the dotted lines and cut along the others. Now paste your paper together to form a cube. Make a cubic inch in the same way. Cover them both with melted paraffin wax to make them waterproof.

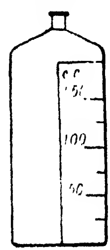


Fig. 152.

8. *To make a graduated cylinder.* Paste a strip of paper up the side of a narrow jam jar or bottle. Now with the aid of your pipette carefully run 50 c.c. of water at a time into the jar, each time accurately marking the level of the water on the paper strip. Divide the space between each of the marks on the strip into ten equal parts. Thus you will have a jar that will measure to the nearest 5 c.c. If your jar is sufficiently narrow you will be able to mark off the strip of paper so that you can measure to 1 c.c. with a fair degree of

accuracy. Ask the boy or girl next to you to check the accuracy of your measuring jar with another pipette.

*9. **To check the accuracy of your measuring jar using the burette.*** Fill your burette with water. The instrument is not ready for use until the tap and jet at the bottom is filled with water. Therefore, open the tap and let water pass through until all the air has been forced out. Now fill your burette to the 0 c.c. mark. Carefully run 1 c.c. or 5 c.c. at a time from the burette into your measuring jar and see if the level of the water and the corresponding mark on the jar are in line.

*10. **To find the volumes of irregularly shaped solids that sink.*** To find the volumes of irregular objects, such as pebbles or bunches of keys, take a measuring jar and pour in some water. Read the level of the meniscus, and then, tilting the jar well, slide your object carefully down the side into the water. See that the water completely covers the object.

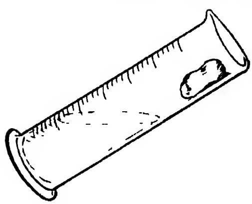


Fig. 153.

Why should you tilt the jar?

Now read the level of the meniscus. Take the first reading of the level of the meniscus from the second one. The result will be the volume of your object.

*11. **To find the volume of irregularly shaped objects which float.*** You can find the volume of a piece of wood or cork by tying it to a "sinker", i.e. some substance which easily sinks. First you must find the volume of the "sinker", and then the volume of the "sinker" and the cork or wood tied to it. By subtracting the volume of the "sinker" from that of both of them, the volume of the cork or wood will be found.

N.B. Solid substances, such as sugar and salt, that dissolve in water may have their volumes determined by immersing them in methylated spirits, paraffin oil, or petrol.

Appendix A

QUESTIONS REQUIRING SHORT ANSWERS

These are intended for periodic test purposes. In the majority of cases the answers should not occupy more than one line.

CHAPTER 1

1. "I have in my hand an ***empty*** jug." Rewrite this sentence so that it is scientifically accurate.

2. How do we know there is air all round us?

3. What is the force with which the air presses?

4. What is a hurricane?

5. When you drink with the aid of a straw what causes the air to press liquid up into your mouth?

6. What animal drinks in this way?

7. What prevents the water inside the magic tin from coming through the bottom?

8. Draw a diagram of an experiment which shows that air presses upwards.

9. What happens to balloonists who rise seven or eight miles in open baskets?

10. Explain this.

11. Draw a portion of a bicycle pump showing how air gets into the barrel.

12. Make a drawing showing how air passes through the valve into the tyre.

13. What is a perfectly empty space called?

14. To what height will the air pressure support a column of water?

15. What is the approximate height of the mercury in a mercury barometer?

16. What is mercury?

17. Where is there a vacuum in this room? (Torricellian.)

18. What is the meaning of "barometer"?

19. What is the height of the mercury column in the barometer equal to?

20. How do barometers indicate the weather?

21. What name is given to those barometers which do not contain any liquid?

22. For what special purpose are they used?

Chapter 2

1. What else is required besides wood and coal if a fire is to continue burning?

2. Why is phosphorus kept in water?

3. Name one purpose for which phosphorus is used.

4. What is formed when phosphorus burns? What do you know about this substance?

5. Write down the names of the two chief gases which are to be found in the air.

6. What happens when iron rusts?

7. What is the chemical name for iron rust?

8. What is an oxide?

9. Say something you know about oxygen.

10. Say something you know about nitrogen.

11. Name two ways in which iron is prevented from rusting.

12. What is silver tarnish?

13. What is the name of that gas which turns lime water milky?

14. Mention two things you know about this gas.

15. What are the names of the two substances used in a fire extinguisher?

16. What happens when these two substances are put together?

17. What makes lemonade bright and sparkling?

18. What is the chief difference between the air we breathe in and that which we breathe out?

19. Why are burning, breathing and rusting very similar to each other?

20. What is it that prevents the air from becoming full of carbon dioxide?

21. Why do we grow green plants in an aquarium?

22. What is a molecule?

23. What is the main difference between solids, liquids and gases?

Chapter 3

1. Name three different sources from which we can obtain our tap water.

2. What is the force that pushes water along pipes to the houses and then out of the taps?

3. From which tap will water come with the greatest force—the one in the bathroom upstairs, or the one in the kitchen downstairs?

4. What is a siphon for?

5. What has to be done to it first in order to make it work?

6. Where does the artesian well get its water from?

7. What is meant by "hard water"? Give an example.

8. What is meant by "soft water"? Give an example.

9. Name two disadvantages of hard water.

10. How can some hard water be made soft?

11. What is the name given to perfectly pure water?

12. How is this water made?

13. What is filtering?

14. Is it possible to filter salt out of salt water?

15. Why is this?

Chapter 4

1. How can you tell if a tap requires a new washer?

2. What is the tap washer made of? Make an actual size drawing of it.

3. When the tap is turned on leakage sometimes takes place in another part close to the handle. What is the name of it?

4. How would you cure this?

5. Draw a diagram of a water trap.

6. What is a water trap for?

7. Draw a rough diagram to show how lakes and sources of rivers receive their fresh supplies of water.

8. What makes the sea water salty?

9. Name two inland seas that are very salty.

10. What is the word we use to describe what is happening to steam when it changes back to water?

11. What is the word used to describe what is happening to water when it is changing to steam?

Chapter 5

1. What is water made up of?

2. What two substances can be put together to make hydrogen?

3. Say three things you know about hydrogen.

4. Can water be manufactured? How?

5. What is helium?

Chapter 6

1. Make a rough diagram showing that water pressure increases with depth.

2. Why do things seem to weigh lighter in water than in air?

3. Why does an iron ship float?

4. Make a rough diagram of a submarine and name its parts.

5. How is a submarine made to sink?

6. Write a fraction, using words, showing what density is.

7. What does this mean?

8. What is meant by Specific Gravity?

9. What is the name of the instrument used for testing the specific gravity?

10. How can we prove that the milkman is being honest by selling us pure milk and not milk and water?

11. What is the Plimsoll Mark and why is it painted on the sides of ships?

12. How can you tell a good egg from a bad one?

Chapters 7–10

1. What is meant by Reproduction?

2. What do plants feed on?

3. Into what two large groups can all animals be placed?

4. What diseases are caused by some Amoeba-like animals?

5. What happens to a worm if it is cut in two?

6. How do Earthworms make their burrows?

7. Name all places where animals similar to the worm can be found.

8. What use was made of Leeches some years ago?

9. What colour are Shrimps, Lobsters, and Crabs when alive, and when dead?

10. What do Snails eat? How do they eat their food?

11. What is the difference between Snails and Slugs?

12. What are the special functions of a flower?

13. What is cross-pollination? What is its advantage over self-pollination?

14. Why do insects visit flowers? How do flowers benefit by their visits?

15. Of what use to a growing seed is the food contained in it?

16. What is the difference between a seed and a fruit?

17. Why is a Spider not called an insect?

18. What insect is the chief enemy of the Cabbage Butterfly? Why is it?

19. Most insects, and also other animals, multiply very quickly. How is it that we are not overrun by them?

20. How can you tell Butterflies from Moths?

21. How can we prevent House flies from spreading disease?

22. How was the Black Death caused?

23. What is "Blight"? How can it be got rid of?

24. How are Bees made use of by man?

Chapter II

1. What is it that prevents us from falling off the earth?

2. What is an orbit?

3. There is a force which attracts one thing to another. What kind of attraction do we call this?

4. What is the scientific explanation of the weight of anything?

5. How do you lose weight without losing any flesh?

6. Why would it be possible for a boy on the moon to jump six times higher than he could on the earth?

7. Why is it sometimes unfair to use a spring balance for weighing?

8. What is the word that scientists use to describe the quantity of material in anything?

9. What causes the tides at the seaside?

10. What are very high and very low tides called?

11. What causes them to be so high and so low?

12. What is the name given to tides which are neither very high nor very low?

13. What is the length of time between one high tide and the next?

14. Why is this?

Chapter 12

1. If you were cast upon a desert island and wished to measure time in hours, what would you do?

2. In similar circumstances, how would you measure lengths of time as short as sixty seconds?

3. Write down the names of two old-fashioned units that were used to measure length.

4. A light year is said to be six million, million miles. What is meant by this?

5. What is the name given to the curved surface of liquids?

6. What is a pipette?

7. Why do the markings on a burette start at the top from 0 c.c.?

8. What does c.c. mean? Draw a cube to represent as near as possible the actual size of 1 c.c.

9. What are measuring jars used for?

10. How would you find the volume of a lump of sugar?

Appendix B

SUGGESTIONS TO TEACHERS AND PUPILS ON GENERAL PROCEDURE

1. The pupils should read certain portions from the book as indicated by the teacher. During this time the teacher will be free to continue preparing apparatus either for demonstration purposes or individual experimental work.

2. Then a short space of time, e.g. ten minutes, should be allowed for general discussion between teacher and pupils. By extending the time it would be best to give demonstration experiments during this period.

It is particularly important that the time allowed for the science lesson should be fairly apportioned in accordance with the demands of the syllabus. This should prevent certain items being stressed at the expense of others.

3. (*a*) No. 2 should be followed, where possible, by individual experimental work.

There is no necessity for the teacher to prepare instruction cards. Sufficient instructions are given at the end of each section of the book.

(*b*) The pupil should record at least the results of his experimental work. It is a good plan to make him write up his work under the following headings:

(i) What I did.
(ii) What happened.
(iii) Why these things happened.

This will give good training in logic and English, and will justify reasonable time being allotted, in the School Time-table, to science.

4. The summary should be copied by the pupils into their note books and learned, and set questions should be answered.

In spite of the demands of the many other subjects in the school curriculum it is strongly recommended that during every week at least one hour is spent over items 1, 2 and 3; and half an hour over item 4 and the answering of the questions appearing in Appendix A.

All work done by the pupils should be recorded. Records of individual experimental work and of the answers given to the questions appearing in Appendix A will be of particular value. If pupils show a good knowledge of the answers to these last-mentioned questions the teacher may rest assured that really valuable work has been done.

In order to avoid confusion over apparatus and the number of experiments performed, it has been found to be a good practice if the experimental work of the pupils is recorded in a manner similar to that indicated in the following copy of a specimen page from a teacher's record book.

Name of Pupil	Title of experiment						
	The Siphon	Testing for hardness of water	Softening water	Splitting up water	Water pressure		
Hall, Reg.	9. 7						
Price, Thos.		9 7					
Smith, Robt.			9 7				

N B. The figures in the columns after the names represent the day and month that the experiment was commenced.

Appendix C

APPARATUS AND MATERIALS NECESSARY

The following is a list of all the material required for the first-year course. The dimensions and general particulars issued are of those pieces of apparatus which it will be most suitable to use.

Items specially marked (printed in italics) are not essential, but if purchased through any surplus in the school allowances or through a school fund they will be found to give added stimulus to the work.

In the case of the aneroid barometer or barograph (see Fig. 20) the suppliers will adjust them for use in any particular school if the height above sea level is supplied when ordering.

All the prices accompanying the apparatus specified have been taken from the catalogue of Philip Harris and Co., Ltd., Birmingham. They are amongst the foremost scientific instrument makers and suppliers in the country, and we are indebted to them for the loan of blocks, and courteous assistance in the examination and choice of suitable apparatus. Customers will find them most willing to give advice in connection with the problems of science apparatus.

2 lb. assorted soft glass tubing. Diam. 3–16 mm.	1*s*. 6*d*. lb.
6 gas jar covers. Ground one side.	7*d*. a dozen.
6 gas jars. Diam. 5 cm., ht. 20 cm.	1*s*. 1*d*. each.
1 lb. mercury	5*s*. to 7*s*. 6*d*. lb.
2 barometer tubes.	1*s*. each.
1 *aneroid barometer or barograph.*	30*s*.
1 bell jar. Diam. 14 cm., ht. 28 cm.	7*s*. 6*d*.
2 glass troughs. Diam. 25 cm., ht. 10 cm.	3*s*. 3*d*. each.
3 tripods.	1*s*. 3*d*. each.
2 Bunsen burners.	1*s*. 3*d*. each.
2 crucibles and lids.	1*s*. 3*d*. each.
3 hard glass test tubes.	2*s*. 6*d*. a dozen.
1 beehive shelf. Diam. 10 cm.	1*s*. 3*d*.

2 deflagrating spoons, with caps	8*d*. each.
2 thistle funnels. Length 20 cm.	3*d*. each.
4 flasks. 375 c.c.	8*d*. each.
4 beakers. 375 c.c.	9*d*. each.
48 test tubes. 5 in. × $\frac{5}{8}$ in.	7*s*. a gross.
2 filtering funnels. Diam. 9 cm.	10*d*. each.
12 ft. india-rubber tubing (red). Interior diam. 8 mm.	5*d*. ft.
4 ft. india-rubber tubing (black). Interior diam. 5 mm.	3*d*. ft.
4 ft. india-rubber tubing (black). Interior diam. 3 mm.	2*d*. ft.
2 retort stands, with bosses and clamps.	5*s*. each.
2 rings for above. Diam. 5 cm.	9*d*. each.
1 condenser, Liebig's. 30 cm.	2*s*. 6*d*.
1 packet of filter papers. 12·5 cm.	1*s*. per 100.
1 gross assorted corks.	7*s*. 6*d*. a gross.
1 spring balance in ounces to 8 lb.	8*s*. 6*d*.
2 hydrometers: (*a*) liquids heavier than water, (*b*) liquids lighter than water. Wide range.	3*s*. 6*d*. each.
1 batswing burner.	1*s*. 6*d*.
6 clips, Mohr's. 5 cm.	2*s*. 3*d*. a dozen.
1 pipette. 10 c.c. Student type.	7*d*.
2 pipettes. 25 c.c. Student type.	10*d*. each.
2 pipettes. 50 c.c. Student type.	1*s*. 1*d*. each.
2 burettes. 50 c.c.	2*s*. 6*d*. each.
1 burette stand to hold two burettes.	4*s*. 3*d*.
1 measuring jar. 200 c.c.	1*s*. 10*d*.
2 light springs for making spring balance.	4*d*. each.
1 lever balance and weights.	37*s*. 6*d*. a set.
1 set iron weights, $\frac{1}{4}$ oz. to 1 lb.	3*s*. 6*d*.
2 iron wire gauze squares.	3*d*. each.
1 triangular file for glass cutting.	6*d*.
2 clay pipe triangles.	2*d*. each.
2 test tube brushes.	2*d*. each.
1 pair crucible tongs.	5*d*.

1 microscope 3310 (recommended); or	77*s*. 6*d*.
1 *micro-projector. The advantage of the micro-projector is that, with suitable screening, magnifications up to 50 diameters can be shown to a dozen or more students at once. A* 6 *volt battery is required.*	80*s*.
1 gross microscope slides. Ordinary quality.	4*s*. 6*d*. a gross.
2 oz. cover slips (round).	4*s*. 6*d*. oz.
6 magnifier triple lenses.	2*s*. each.

Prepared slides

Hydra.
Hydra budding.
Hydra with swallowed animal.
Body louse.
Head louse.
Amoeba.
Gnat male.
Gnat female.
Bed bug.
Tongue of bee.
Tongue of blowfly.
Tongue of butterfly.
Tongue of house fly.
Mouth organs of flea.
Mouth organs of gnat.
Mouth organs of garden spider.
Foot of house fly.
Sting of bee.
Sting of wasp.
Wing of bee hooked.
Wing of bee unhooked.
Spiracle of blowfly.
Trachea of blowfly.

1*s*. 6*d*. each or 15*s*. a dozen.

Chemicals

1 oz. magnesium ribbon.	1*s*. 6*d*. oz.
6 candles.	½*d*. each.
2 lb. sodium carbonate (commercial).	2*d*. lb.
1 W. Qt. sulphuric acid (commercial).	2*s*. 6*d*. W. Qt.
1 pt. hydrochloric acid (commercial).	3*d*. lb.
1 pt. nitric acid (commercial).	8*d*. lb.
1 lb. potassium chlorate (commercial).	9*d*. lb.
1 lb. manganese dioxide (commercial).	5*d*. lb.
1 lb. sulphur.	5*d*. lb.
1 oz. phosphorus.	6*d*. oz.
1 lb. lead shot.	10*d*. lb.
2 lb. granulated zinc.	10*d*. lb.
4 oz. chloroform.	10*d*. oz.
1 lb. formaldehyde (44 per cent.).	1*s*. 2*d*. lb.

The following articles, which can be obtained from any ironmonger, will be found very helpful, particularly to boys who are keen on ***constructing their own models*** of apparatus:

A jack plane, a smoothing plane, two chisels ¼ inch and ½ inch, one tenon saw, and a brace with three or four various sized bits.

Appendix D

HINTS ON THE USE OF APPARATUS AND PREPARATION OF CERTAIN MATERIALS NECESSARY FOR THE FIRST-YEAR COURSE

The Bunsen Burner. For ordinary purposes this burner will be used with the air hole at the bottom a little more than half open. This will give a hot smokeless flame.

Clay pipes are used to support articles on a tripod that have to be heated strongly, e.g. crucibles.

Iron wire gauze is used when such fierce heating is unsuitable,

and sandbaths (tin trays something like saucers that contain sand) are used when very slow heating is required.

For cleaning glass vessels. Hot or cold water and, perhaps, soap will be sufficient; if not dilute hydrochloric acid or dilute nitric acid should be used (the latter is the more effective).

Copper sulphate and potassium permanganate stains on glass may be removed by rubbing vigorously with Glitto, Gry-moff, or Gre-solvent.

Acid burns. If a drop of acid falls on to your clothes it will slowly burn a hole in the cloth. This may be stopped, however, if some ammonia is dropped on to the acid, or if a lump of washing soda is held firmly against it. The washing soda or the ammonia kills the action of the acid.

If acid falls on your hands or face wash it off immediately with plenty of water.

Test tubes should be held with their mouths pointing away from you or from anyone else.

A holder to hold them in the Bunsen flame can be made from a piece of paper. The paper should be folded into a strip of several thicknesses. You can then grip the test tube with the paper strip in much the same way as a nut is gripped with the nutcrackers.

Removing glass stoppers from bottles. The stopper may often be loosened by knocking the neck of the bottle gently against the bench. Failing this the neck of the bottle should be warmed by pulling a thick cord or cloth round it several times. In very obstinate cases the stopper can be removed by carefully and gently warming the neck with a match flame.

To cut the bottoms off glass bottles. File round the bottle where you wish the break to be made. The filing will be easier if the file is dipped occasionally into turpentine. The final break can now be made by either of the following methods:

1. Hold the bottle in boiling water with the file mark level with the surface of the water.

2. Tie round the file mark a piece of string that has been dipped into methylated spirits. Light the string. The heat will crack off the bottom of the bottle.

To dilute acids. Acids are diluted when they are mixed with water, ***but the acid should always be poured into the water.*** When sulphuric acid is mixed with water a great deal of heat is formed, and by adding the acid to the water there is less danger of the heat causing the acid to be shot out of the vessel.

Distilled water. For making distilled water see page 43.

Iodine solution can be made by dissolving the solid crystals in either methylated spirits or potassium iodide solution.

Lime water. See page 36.

Saturated solutions in water of substances are made by continually adding a little of the substance until no more will dissolve. Consequently a little of the substance will always be left at the bottom of the vessel.

The substance which is being dissolved is called the ***solute,*** and the liquid which does the dissolving is called the ***solvent.***

Appendix E

REFERENCE BOOKS

[These books are intended chiefly for identifying specimens.]

Bentham and Hooker. *A British Flora.* 2 vols.

Johns, Rev. C. A. *Flowers of the Field.*

—— *British Trees.*

Step, Edward. *Wild Flowers Month by Month. In their Natural Haunts.* 2 vols.

—— *Wayside and Woodland Blossoms.* Series I, II, III.

Thompson, H. S. *How to collect and dry flowering plants and ferns.*

BOULENGER, E. G. *The Aquarium.*
DUNCAN, F. MARTIN. *Cassell's Natural History.*
EES, RICHARD SOUTH. *Moths of the British Isles.* 2 vols.
FURNEAUX, W. *The Sea Shore.*
—— *Life in Ponds and Streams.*
JOY, NORMAN H. *British Beetles. Their homes and habits.*
LULHAM, R. *An Introduction to Zoology through Nature Study.*

Shown to the Children Series:

KELMAN, J. H. *Butterflies and Moths.*
—— *Bees.*
STEP, EDWARD. *Bees, Wasps, Ants and Allied Insects of the British Isles.*
—— *British Insect Life.*
WYSS, C. VON. *Living Creatures.*

Appendix F

HOW TO FIND AND KEEP ANIMALS

Amoebae can be bought from dealers, or cultured in water in which grains of corn have been allowed to decay.

Hydra can be bought from dealers although it can be found (see page 75). It can be kept in an aquarium, but it must be fed occasionally on Daphnia. Add pond water to tank carefully. Tap water kills the Hydra.

Earthworms. In a dry season if worms cannot be obtained, watering a patch of grass thoroughly, or stamping on the ground, will bring worms to the surface.

Leeches can be found in ponds, streams or canals and will feed on fish, tadpoles or worms. Cover the top of the aquarium or Leeches will get out.

Woodlice are found under damp or rotting wood.

Water snails are plentiful in most ponds, streams and canals, and can also be bought from most local live-stock dealers.

Land Snails and ***Slugs*** can be found in the country, but are difficult to find in towns.

Insects

Butterflies and Moths. These are easily kept in school if the caterpillars are fed on the proper food. Caterpillars will not eat any plant, but only those on which they are found.

Silkworms can be bought from dealers and will eat Lettuce if no Mulberry is available.

Blowfly larvae can be bought from any shop that sells fishing tackle. Stick Insects can be bought from dealers. They are easy to keep, feeding only on privet.

Other Insects

Insects are easily kept if fed on the proper food. Details of insects not mentioned in this book will be found in the Reference Books.

Insect larvae living in water will live in an aquarium, if this is properly set up.

Preserving Specimens

Large insects, such as Beetles, can be kept in a 2 per cent. solution of formaldehyde, which also kills them.

Smaller insects, such as Flies and Butterflies, can be killed by putting them into a killing bottle containing cotton wool soaked in chloroform. A dry piece of cotton wool should be put on top so that the insect remains dry. When the insect is dead, spread out its wings before it stiffens and place it in a glass-topped box to keep off the dust. Butterflies and Moths should not be exposed to the light or their colour will fade.

The Aquarium

Put a mixture of silver sand and medium-sized stones at the bottom of the aquarium and plant a selection of water plants.

[People in town can buy these from dealers.] If the plants and animals are well balanced the water should not need changing. Should the water need changing, siphon water in and out at the same time, if possible. If not, take out a few jars of water, and replace with clean water. It may be necessary, occasionally, to empty the aquarium and wash the silver sand; afterwards replacing the sand and weeds.

Dealers in specimens of livestock

Names of dealers may be obtained from the journal of the "School Nature Study Union." This can be obtained from the Secretary, Dr Winifred Page, 5 Dartmouth Chambers, Theobalds Road, London, W.C. 1.

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